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A/RIA SYSTEM
CATEGORY II FINAL TEST REPORT

July 1967

AEROSPACE INSTRUMENTATION PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

(Prepared under Contract No. AF 19(628)-4888 by Douglas Aircraft Modification Division, 2000 N. Memorial Drive, Tulsa, Okla. 74115.)

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APPENDIX I

SYSTEM DESCRIPTION

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APPENDIX I

SYSTEM DESCRIPTION

GENERAL

The A/RIA System was designed under the basic concept of modifying an inventory aircraft — in this case the C-135A — by installing sufficient radio, voice and data communications equipment to enable the orbiting Apollo space vehicles to maintain two-way communications with the world-wide space vehicle control network operated by NASA and the Air Force. Such an installation required the addition of a sensitive directional antenna system, and several omnidirectional antennas, to insure two-way voice communications, data reception from the spacecraft, and data retransmission to established ground stations. The general configuration of the aircraft is illustrated in Figure I-1. The installation of the prime mission electronics equipment (PMEE) required significant modifications to the interior of the aircraft, plus extensive modifications to the original electrical and air conditioning subsystems. The major subsystems of the PMEE (and aircraft modification) will be described in the succeeding paragraphs.

AIRCRAFT MODIFICATION SUBSYSTEM

The modification of the basic C-135A to the EC-135N A/RIA aircraft consisted of extensive modifications to the cabin area to accommodate the PMEE and the operating crew. The general configuration of the interior of the aircraft showing equipment and crew positions, and installation of the nose-mounted UHF/VHF tracking antenna, is presented in Figure I-2.

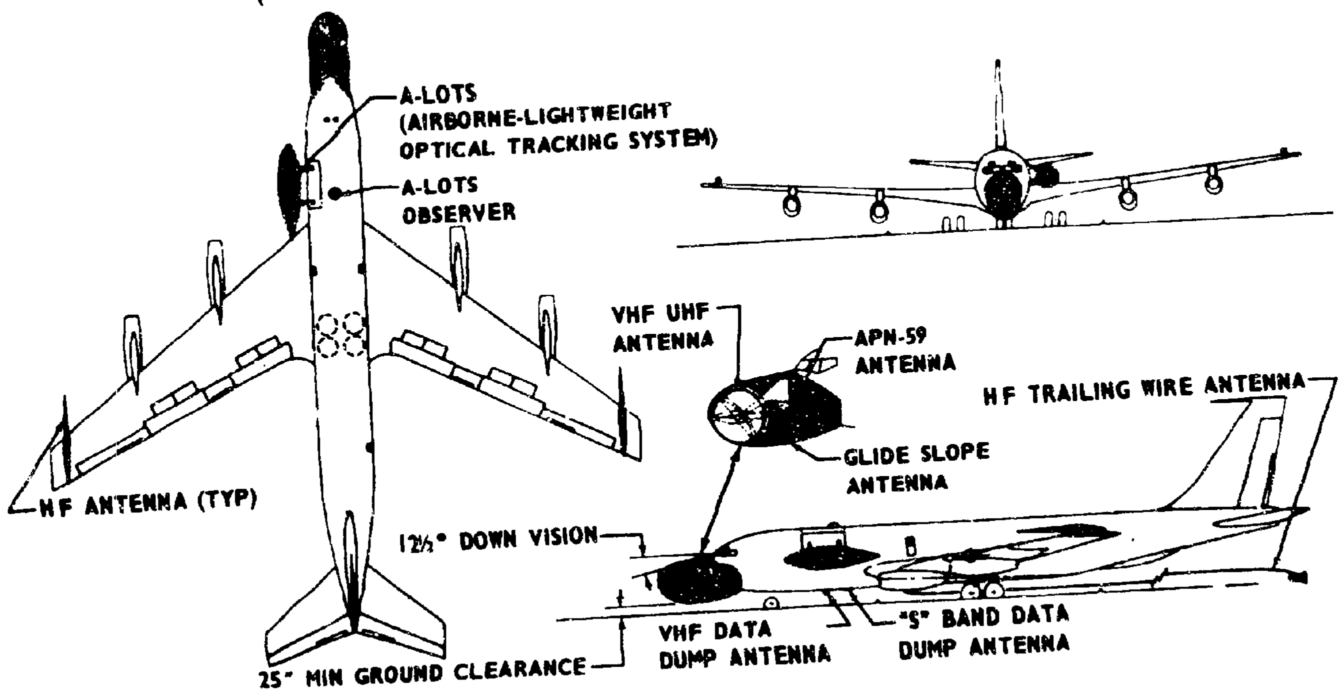
Structural System

Installation of the PMEE required modification and local strengthening of the floor, plus the addition of provisions to provide upper cabinet attach points. Additionally, support provisions were added for the cabling and cooling ducts associated with electrical power and cooling of the PMEE. To support the operating crew, two rest areas were added: a forward rest area, located just aft of the flight crew compartment, and an aft rest area at the rear of the cabin. Personal equipment and storage provisions were installed at various positions throughout the cabin area.

The nose area modification consisted of major re-work to the bulkhead at Station 178 to provide support and attach provisions for the UHF/VHF tracking antenna and associated radome. Fairing structure was added aft of Station 178 to minimize aerodynamic effects of the modified nose. Figure I-3 illustrates the installation of the tracking antenna and fairing structure.

Other minor structural modifications were required for the addition of the HF wing-tip and trailing-wire antennas, addition of data dump antennas, relocation of the existing C-135A navigation and communications antennas, static reference port, and pitot tubes. Those aircraft designated to include the ALOTS subsystem required some strengthening of the cargo door frame and structure to accommodate the cargo-door-mounted ALOTS pod.

A/RIA
(APOLLO/RANGE INSTRUMENTED AIRCRAFT)



Aircraft Empty Weight 122,500 pounds - ALOTS 128,450 pounds
Design Useful Load 147,500 pounds - ALOTS 141,500 pounds
Design Gross Weight 270,000 pounds
Maximum Taxi Gross Weight 279,500 pounds

Figure I-1. EXTERNAL CONFIGURATION

A/RIA A-LOTS
INBOARD PROFILE AND FIXED EQUIPMENT

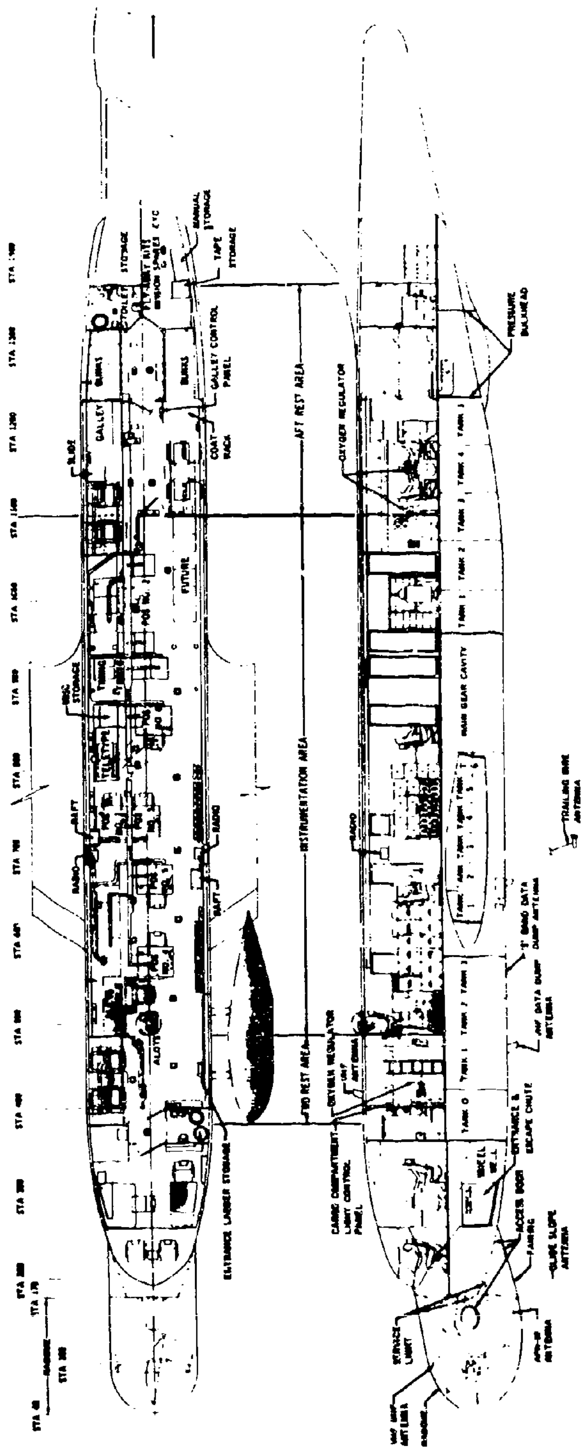


FIGURE I-2 A/RIA AIRCRAFT INTERIOR CONFIGURATION

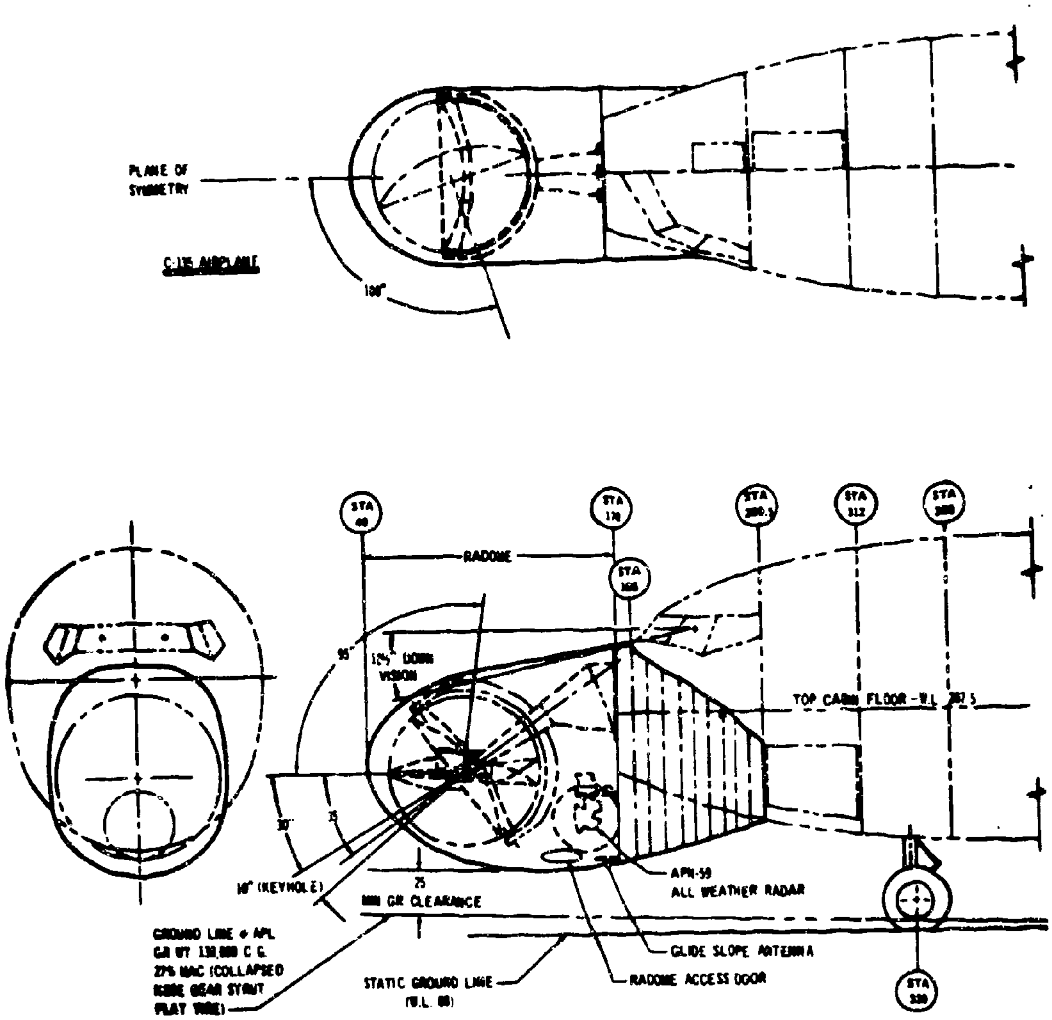


FIGURE I-3. NOSE RADOME AND FORWARD ANTENNA INSTALLATION

Electrical Power System

The electrical power generation capability was increased to meet the additional load imposed by the PMEE. Existing generators were removed and replaced with 40-KVA brushless generators on all four engines to provide a 160-KVA, four-channel, automatic paralleling system to meet the requirements of the basic aircraft and PMEE subsystems — and the ALOTS, for those aircraft so configured. The brushless generators were chosen for the system to improve the reliability and maintainability of the system, and to minimize the possibility of electromagnetic interference.

Air Conditioning and Pressurization System

The existing air conditioning system was augmented with a forced-air circuit to provide for the increased cooling requirements imposed by the PMEE. This circuit consists of a skin heat exchanger, supply and return ducting, and two electric motor-driven fans. In addition, a mixing valve is included to provide heated air to the PMEE cabinet system to prevent over-cooling of the equipment.

The basic C-135A air conditioning system was unaltered, except for modification of the overhead ducts to provide conditioned air to the PMEE operators and the new rest areas, and relocation of the pressurization static reference source.

Navigation/Communications Systems

Installation of the tracking antenna, radome, and the PMEE necessitated the relocation of the antennas of the SCR-718 Radio Altimeter, AN/ARN-21 TACAN No. 2, AN/ARN-67 Glideslope, and AN/APN-59 Search Radar.

The complement of antennas was expanded to accommodate the communications requirements of the A/RIA System. The spacecraft-to-A/RIA data and voice relay link is accomplished by the large nose-mounted UHF/VHF steerable antenna. This antenna has automatic tracking capability to insure continuous voice communications. To handle the A/RIA-to-ground voice relay link, an HF trailing-wire antenna was installed (see Figure I-4). Two HF wing-probe antennas were installed to improve the system reliability; in addition, the vertical fin probe is tied into the PMEE and to the pilot's HF system. Two data dump antennas were also added to provide A/RIA-to-ground transfer of recorded telemetry data relayed from space vehicles.

The basic C-135A intercommunications system was extensively modified to provide selective and "party-line" communications among the PMEE operators. In addition, radio communications and emergency call provisions are supplied to the new intercom system positions. During normal operations, tie-in of the PMEE operator positions with the flight crew positions can be established only through the A/RIA Mission Coordinator position.

Support Systems

The basic C-135A lighting system has been modified to provide the necessary illumination at the various PMEE operator positions and rest areas. Other

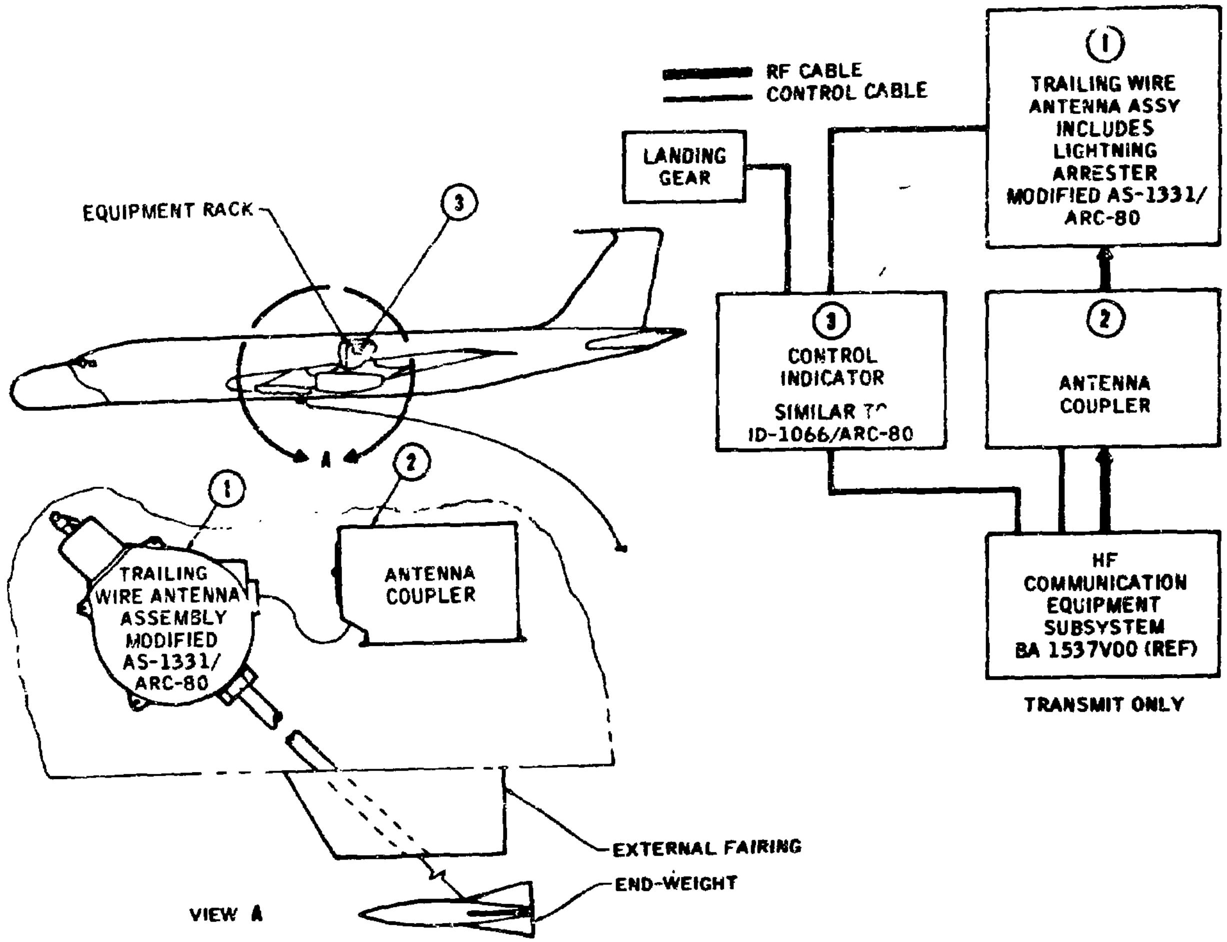


FIGURE I-4. TRAILING WIRE ANTENNA SUBSYSTEM

equipment modifications include extension of the oxygen system to all positions, modification of the emergency alarm system, and installation of a rain-repellent system with the kit provided by the Air Force, in accordance with Technical Order 1C-135-644. The oxygen system on the production of EC-135N aircraft has been converted from the existing LOX system to a GOX system, to facilitate remote area servicing.

PMEE SUBSYSTEM

The PMEE subsystem consists of several subsystems and consoles integrated into a complete electronics subsystem to accomplish the mission of the A/RIA System. For convenience, the PMEE subsystem has been separated into the following functional breakdown, to facilitate description of the composition and operation of the complete subsystem.

Voice and Telemetry Subsystem

The voice and telemetry subsystem includes the assemblies, controls, and equipment discussed in the following paragraphs.

Antenna Assembly

The antenna assembly includes a parabolic dish with a six-terminal spiral feed for UHF and four crossed dipoles for VHF, antenna pedestal and drive assembly, and microwave receive and transmit components.

Antenna Control

The antenna control includes a console housing all control and status indicators for the antenna system.

RF Equipment Group

The RF equipment group includes the tracking receivers, data and voice receivers, UHF and VHF voice transmitters, verification receivers, patch panels, and associated equipment.

Record Equipment Group

The record equipment group includes the wideband data recorders, audio recorder, patch panels, and associated equipment.

Data Dump Equipment

The data dump equipment includes a VHF and UHF transmitter, modulator, and patch panel.

Timing Subsystem

The timing subsystem includes a primary and secondary time standard, time signal generators, WWV receiver, remote GMT and elapsed time indicators, and other equipment used in establishing time codes.

HF Subsystem

The HF subsystem includes HF receivers and transmitters, teletype equipment, telegraph tone terminal equipment, and associated hardware.

Master Control Console

The master control console includes controls and indicators necessary for controlling/monitoring PMEE operations.

A block diagram of the interconnection of the cited subsystems is presented in Figure I-5. A further breakdown and description of the system follows.

Voice and Telemetry Subsystem

The voice and telemetry subsystem is described in the following paragraphs and is shown in the block diagram of Figure I-6.

Antenna Group

The antenna group (antenna assembly and control) consists of a two-axis tracking antenna and control system which drives the antenna in either acquisition or tracking modes. The antenna pedestal and drive motors are located in the nose of the aircraft, while all antenna controls are conveniently located on an operator's control console within the instrumentation compartment. Thus, the operator can control azimuth and elevation inputs manually, can select either acquisition or auto-track mode, and has controls for a tracking combiner.

During acquisition, the operator inserts the azimuth and elevation of the target into the control system by means of the azimuth and elevation knobs. Data from the aircraft directional and vertical gyros stabilize the antenna to the reference point in space selected by the azimuth and elevation inputs until these manual inputs are revised or the system is placed in the auto-track mode of operation. In the auto-track mode, signals received from the tracking receivers are used to automatically drive the antenna on a continuous target track.

The major characteristics of the antenna can be summarized as follows:

a. The pedestal. Two-axis airborne-mount canted -35° from the longitudinal axis of the aircraft and mounted on a vertical plane. An illustration showing the mount gimbal geometry is shown in Figure I-7.

b. Angular coverage. Azimuth ±100° relative to aircraft heading, Elevation -30° to +95° with respect to the horizontal plane. From the illustration it can be readily seen that in order to scan horizontally, it is necessary to rotate both axes.

A beam tilt function has been incorporated to minimize multipath at VHF. This is accomplished by electrically shifting the horizontally polarized elements of the beam by 0°, 11°, 16°, 20°, or 23° in elevation. There is

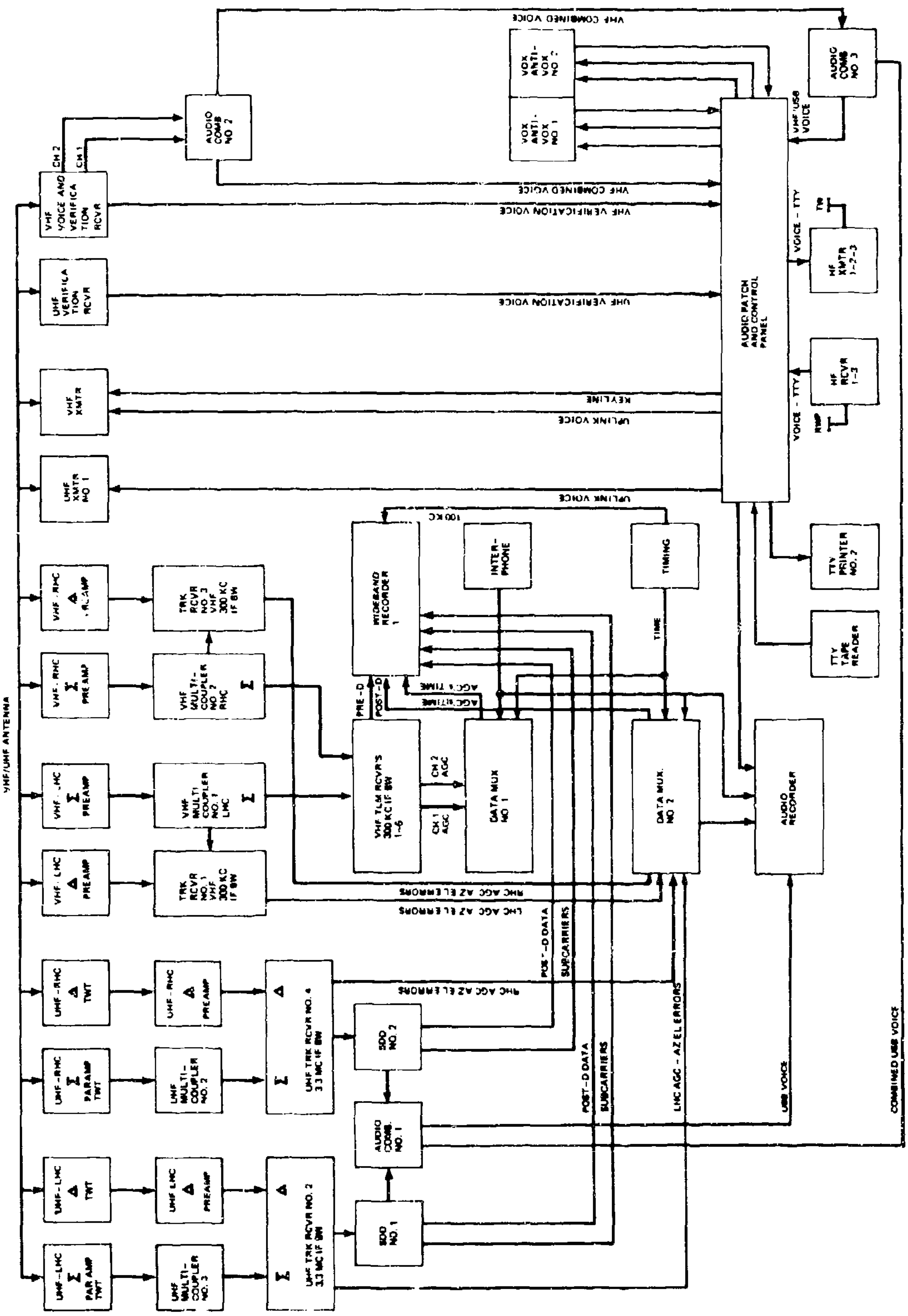


FIGURE I-5. INTEGRATED SYSTEM BLOCK DIAGRAM

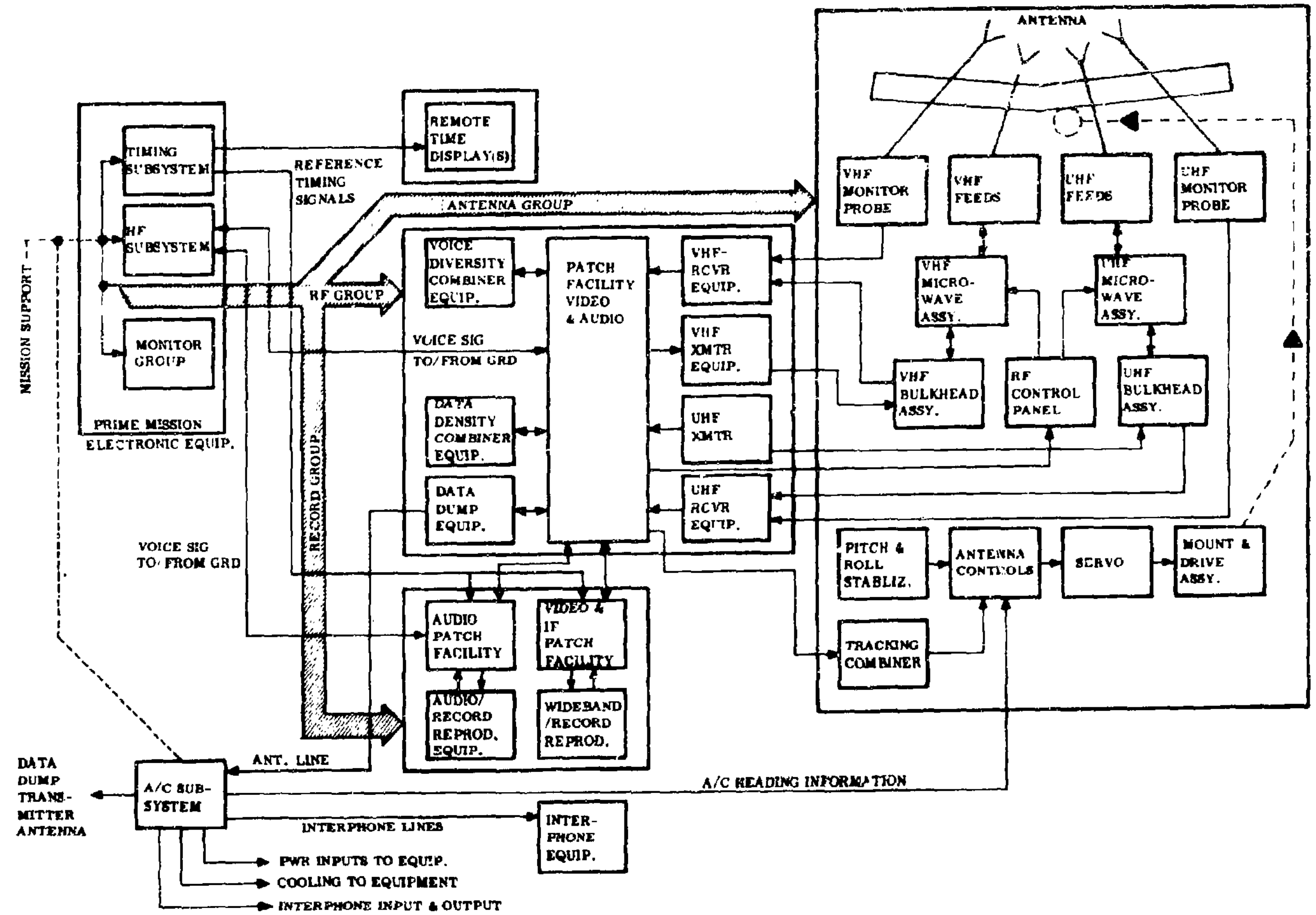


FIGURE I-6. VOICE AND TELEMETRY BLOCK DIAGRAM

no mechanical movement of the antenna and there is no effect on the vertical dipoles. Beam tilt is the most effective with the antenna at a zero azimuth position because, in order to scan the antenna azimuthally, the dish must be rotated; therefore, the shift of the horizontal dipoles would occur at some angle with components in both the azimuth and elevation planes.

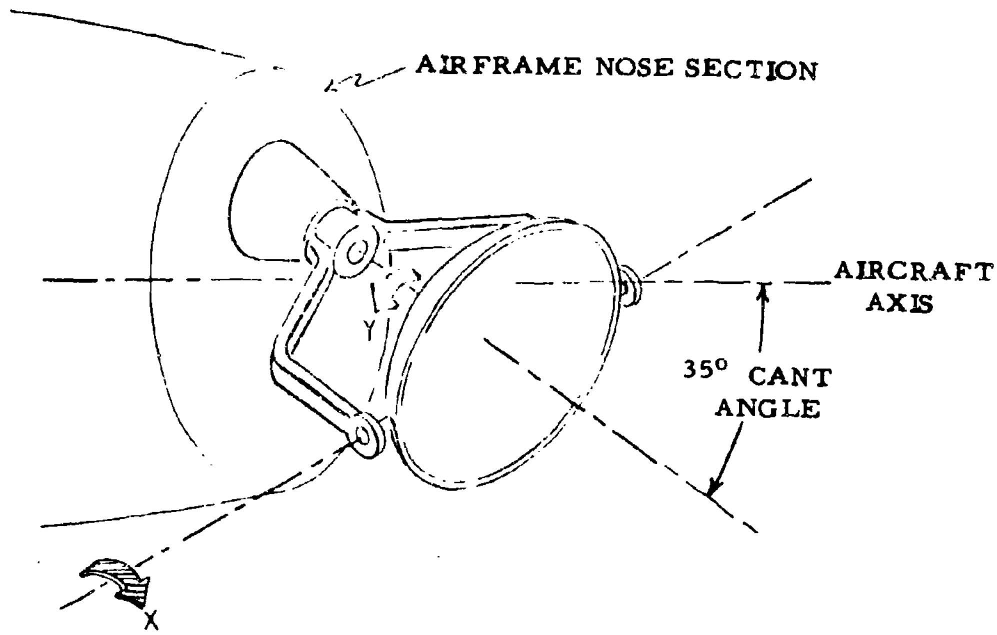


FIGURE I-7. ILLUSTRATION OF ANTENNA GIMBAL

The tracking combiner allows selection of combinations of tracking receiver signals and polarizations to optimize signals to the servo drive system. A simple tracking-rate memory circuit is included which, in the event of a tracking receiver signal loss, will have stored the latest receiver inputs and will continue to drive the antenna pursuant to the stored data.

RF Equipment Group

The RF group supplies antenna directional information, voice transmission to/from the spacecraft, and accepts spacecraft telemetry data. RF capabilities encompass S-band, L-band, and VHF.

Each receiver channel is made up of two independent circuits operating on different senses of polarization. Combination after detection provides high-quality, reliable voice communication. Redundant transmitters are provided on the UHF band; while one transmitter is actively coupled to the antenna, the redundant transmitter is in "hot standby" at all times into a dummy load. Voice signals are injected to modulate both transmitters at all times; thus rapid transfer can be accomplished in the event of failure or malfunction. Voice verification receivers operating from RF probes on the

tracking antenna provide side tone for the operator, giving positive indication that the voice signals are actually being radiated to the spacecraft.

Record Equipment Group

The function of the record group is to record telemetry and voice signals received from the spacecraft and to avail these signals through airborne or ground network playback. The recorders will accept wideband predetection IF signals, medium bandwidth PCM telemetry signals, narrow-band data signals, audio signals, time code, and speed control signals. Auxiliary monitoring equipment to provide visual examination of pre- and post-recorded signals on oscilloscopes, meters, and spectrum analyzers is contained within the system. A playback facility is provided so that an airborne telemetry dump can be accomplished via the ground communication link. The record group comprises the following equipment:

a. Wideband Telemetry Tape Recorder/Reproducers. The primary function of the airborne tape recorder/reproducer is to record predetection, post-detection, video, and low frequency analog telemetry signals. The tape recorders are 14-channel magnetic type, rack-mounted, and are complete with associated electronics and integral controls. Each recorder has 14 direct-record channels, and two FM record channels with provision for expansion to 14 FM record channels. Each rack contains patching panels and switching to permit the use of FM electronics on any given channel. The recorders are capable of accepting IF and video signals during a short mission interval. At a later time, one of the recorded channels is reproduced and its signal fed to a patch panel for transmission to a ground station.

b. Narrow-Band Data Multiplexer. The narrow-band data multiplexer permits a number of narrow-band data signals to be recorded on FM subcarriers. These signals consist of 18 IRIG FM subcarriers ranging from channel number 1 at 400 $\pm$30 Hz to channel 18 at 70 $\pm$10.5 KHz. The record/reproduce systems accept and play back these signals.

c. Audio Tape Recorder.— Seven-Channel. The audio tape recorder is used to record voice communications and consists of three subsystems: a tape transport and associated electronics, record/reproduce electronics, and a monitoring system. The tape speeds provided are 15, 7-1/2, 3-3/4, and 1-7/8 ips. Speed range is selected by means of a belt change, and each speed is accurate to 0.25 percent. Accuracy is maintained over the length of the tape reel when operating with standard aircraft power supply. The transport accepts standard 10-1/2-inch NAB reels, utilizing 1/2-inch tape with a thickness of 1.0 or 1.5 mils. Panel controls are provided for record, drive, stop, fast forward, rewind, and power functions.

d. Predetection Playback Monitor. Predetection up-converters are provided to permit any predetection recorded signal to

be connected to a spectrum display unit for the comparison of the pre- and post-recorded signals. Two switches connect the input of the monitor to any desired track of the tape recorder and the output of the monitor to a spectrum display unit. The output is also connected to the video patch panel for use by a receiver demodulator.

e. Data Multiplexer Calibrator. The data multiplexer calibrator contains a tunable discriminator which will isolate each of the IRIG channels from the multiplexer composite signal. The frequency, potential, and wave form of each signal may be observed on the meter and display scope provided. Calibration of the narrow-band data multiplexer may be accomplished in this manner.

f. Recorder/Reproducer Control Panel. The recorder/reproducer control panel contains the controls, selected switches, signal distribution capability, meters and indicators required to operate and monitor the status of the record/reproduce subsystem.

g. Data and Recorder Error/Multiplexer. The data and recorder error/multiplexer provides higher signal fidelity by separating the wow and flutter components inherent in the recorder from the data and information composite signals.

Data Dump Group

The function of the data dump group is to retransmit to the ground station the telemetry data received from the spacecraft via the VHF and UHF link. This link utilizes two transmitters operating on different frequencies. Separate or simultaneous transmission is possible. The data dump group comprises the following equipment:

a. VHF Dump Transmitter. A 0.5-watt FM data dump transmitter operating in the 215- to 260-MHz band transfers recorded data to ground stations that come into communications range during A/RIA aircraft flight.

b. UHF Dump Transmitter. A 0.5-watt FM data dump transmitter operating in the 2200- to 2300-MHz band transfers recorded data to ground stations that come into communications range during A/RIA aircraft flight.

c. Video Patch Panel. The video patch panel is used to interconnect the VHF dump transmitters to the recorded data. This arrangement will permit modulating both transmitters with the same data or modulating the transmitters with two separate recorded tracks.

d. Antennas (VHF and UHF). The VHF antenna is a broadband antenna permitting operation in the 215- to 260-MHz range. The UHF antenna is a broadband antenna permitting operation in the 2200- to 2300-MHz range.

Timing Subsystem

Timing Group

The timing group is the central timing facility for the A/RIA System. Standard time formats are provided through two distinct time signal generators and power supplies, thereby enhancing reliability through use of redundant generators for the critical timing requirements. An additional radio frequency WWV receiver is furnished to provide verification of frequency primary time standards, and two highly stable accurate time standards provide an on-board frequency reference. A coincidence monitor provides continuous format "display and indicate" coincidence between like signals from the on-board timing system while the A/RIA aircraft is either airborne or on station. Further included are switching panels, patch panels, distribution system, oscilloscope and indicator displays. A block diagram is shown in Figure I-8.

The timing group comprises the following equipment:

a. Frequency Standard, Rubidium. This unit constitutes the primary standard source of highly accurate and stable frequency reference using rubidium. Long-term stability is 5×10^{-11} (standard deviation) for 1 year and short-term stability is 1×10^{-11} (standard deviation) for 1-second averaging time.

b. Frequency Standard, Crystal. A secondary frequency standard consisting of a crystal oscillator is used as back-up for the rubidium oscillator. This unit is part of the monitor panel and senses any inactivity in the rubidium standard.

c. Time Signal Generators. Two time signal generators (TSG) in parallel are used to provide the basic timing pulses of the timing subsystem. Each TSG accepts a 100-KHz input signal, and provides binary code decimal (BCD) and decimal outputs of time-of-year time displays, serial codes, and parallel repetition rates.

d. Time Coincidence and Switch Panel. The outputs of both TSG's are fed into the coincidence monitor panel. This unit contains the circuitry necessary to monitor and check format coincidence between any 12 like codes with a time displacement tolerance of 50 μs. A manual switching capability is provided so that any code or repetition rate may be independently switched from either TSG to the patch panel.

e. Power Supply and Battery Chargers. Each TSG has a power supply and battery charger unit associated with it. The power supply provides DC power to the TSG. It contains all the necessary circuitry to develop the required DC voltage from either the AC power line or the 28-volt battery power supply. In addition, a battery charging

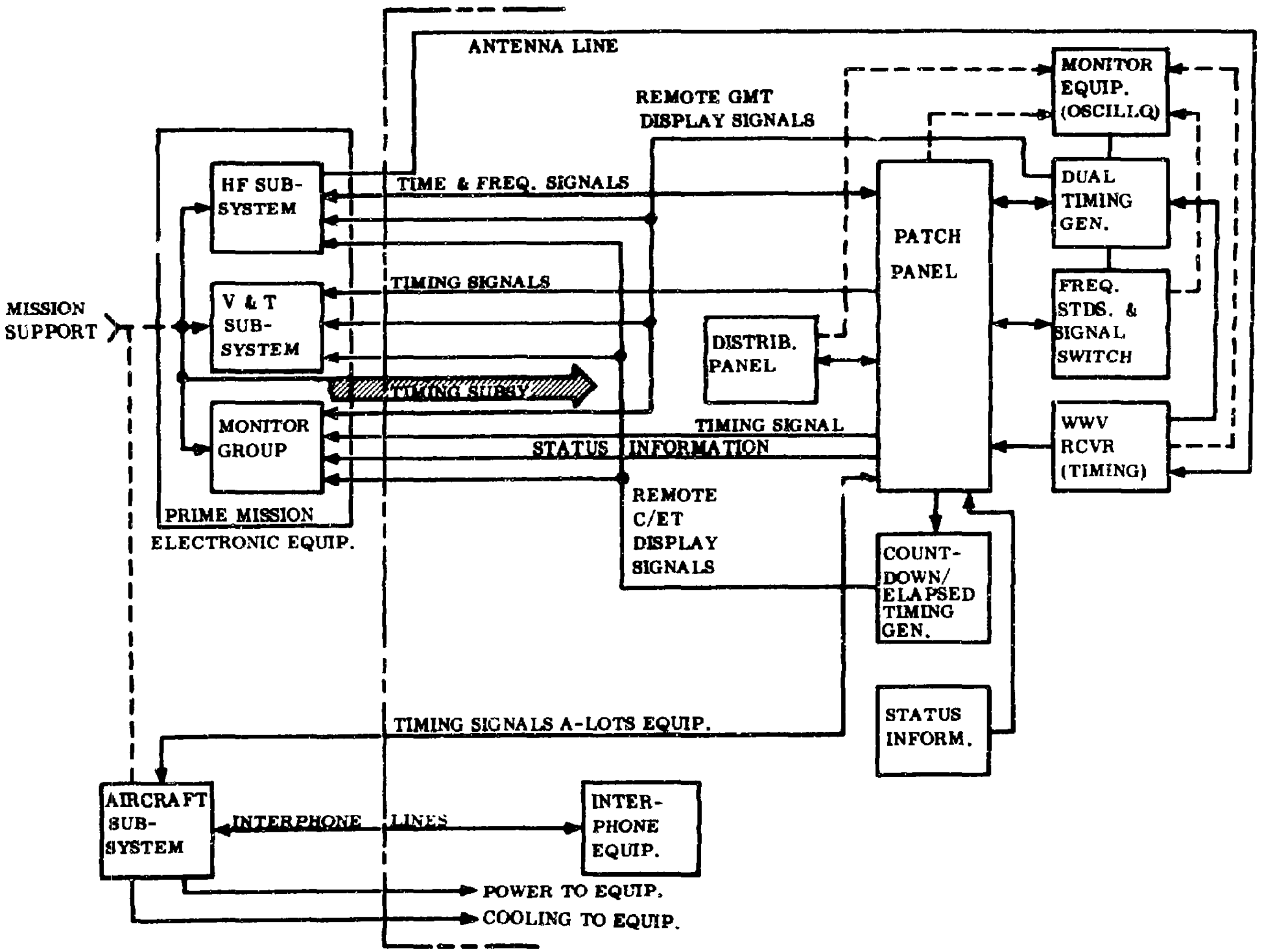


FIGURE I-8. TIMING SUBSYSTEM BLOCK DIAGRAM

supply is provided to continuously trickle-charge or fast-charge the battery when required.

f. WWV Receiver. The WWV receiver is used to receive the transmitted master timing signal for comparison with the on-board clock station. Time comparison readings are taken when the zero crossing of the second cycle of the received WWV tick is aligned with the neutral center line of the CRT. Accurate time synchronization may be performed using corrections for propagation delay and indicator readings. Controls for phasing the locally derived pulse and for inserting the WWV propagation delay are located on the TSG. Using this method, a setting accuracy of ± 5 ms or better with respect to UT-2 can be obtained.

g. Elapsed Time Display. The elapsed time display provides means for monitoring elapsed time and for generating the elapsed time for distribution to remote indicators located throughout the aircraft. The clock consists of an accumulator plus manual and automatic controls for the insertion of elapsed time, start of elapsed time, and for the control of the counting mode. A numeric tube display composed of six nixie tubes indicates mission elapsed time (MET).

h. Timing Distribution Panel. The distribution panel accepts output signals from the time signal generators which are routed through the patch panel and contains circuits which provide voltage and power amplification, and signal mixing; pulse width generation equipment is also incorporated.

i. Battery Power Supply. A battery power supply consisting of a nickel-cadmium storage battery pack is provided as a source of energy power. In the event of a primary power failure, the battery power supply will adequately power a TSG for a minimum of 24 hours and both TSG's for a minimum of 8 hours.

j. Power Control Panel. The system power control panel provides the necessary control and monitoring functions of both AC and DC power for the timing subsystem. In addition, monitoring of both time signal generator power supplies, both battery power supplies, the coincidence monitoring and switching panel, and form distribution panels is accomplished by this panel.

k. WWV Antenna Matching and Filter Panel. The antenna coupler provides a 50-ohm match to the filter input at the five desired WWV frequencies. A five-position motor-drive coaxial switch controls the selection of five fixed-tuned, antenna-coupler matching networks, and provides the digital input for tuning the receiver filter. A filter gain control and over-load indication is also provided.

HF Communications Subsystem

The HF communications subsystem includes equipment to provide voice and teletype communications between the A/RIA and ground stations. A block diagram of the subsystem is presented in Figure I-9. Major HF components are described in the following paragraphs.

HF Transmitter

The HF transmitter is comprised of an exciter and a linear power amplifier. This equipment has performance characteristics as outlined below:

a. Exciter. The exciter translates audio inputs first to a 100-KHz IF and then to a 500-KHz IF in the IF translator unit. This translator unit, when implemented by the appropriate series of single- and dual-balanced modulators, will multiplex up to four independent audio inputs into 2.69 KHz (nominally 3 KHz) channels. The receivers are equipped for two 3-KHz channels with provision for expansion to four channels by the addition of the appropriate plug-in boards. The composite signal includes reinserted carrier, when desired, and permits operation in the compatible AM mode, in the suppressed carrier mode for SSB and DSB, or in the pilot carrier mode for SSB and DSB.

   The 500-KHz IF is translated to the desired frequency in the 2.0- to 29.9999-MHz range by the RF translator with a peak envelope power level of 0.4 watt, suitable for driving the power amplifier. Injection frequencies employed in the two translators are derived from an external 100-KHz standard, having a stability of better than one part in 10^{10} per day. Each transmit channel is individually controlled in 0.1-KHz increments yielding a total of 280,000 channels. A transmit gain control voltage in the RF translator may be set to establish the drive level to the final power amplifier. Feedback is employed to hold the transmit power level in accordance with a preset reference. Remote frequency and mode control of the exciter is accomplished with the radio set control.

b. Power Amplifier. The linear power amplifier operates over the 2.0- to 29.999-MHz frequency range with an output level of 1-kw PEP or average. When coarse-tuned by the system control unit to the nearest megacycle of operating frequency, the unit automatically tunes to the exciter frequency and linearly amplifies the signal. A signal power of 0.2-watt PEP is required to drive the amplifier to rated output. The maximum tuning time of the amplifier is 10 seconds (2 to 3 seconds typical). The gain of the amplifier is within 3 dB (+2, -1 dB of rated output) for all operating frequencies. Except for the RF power stages, the power amplifier is completely transistorized.

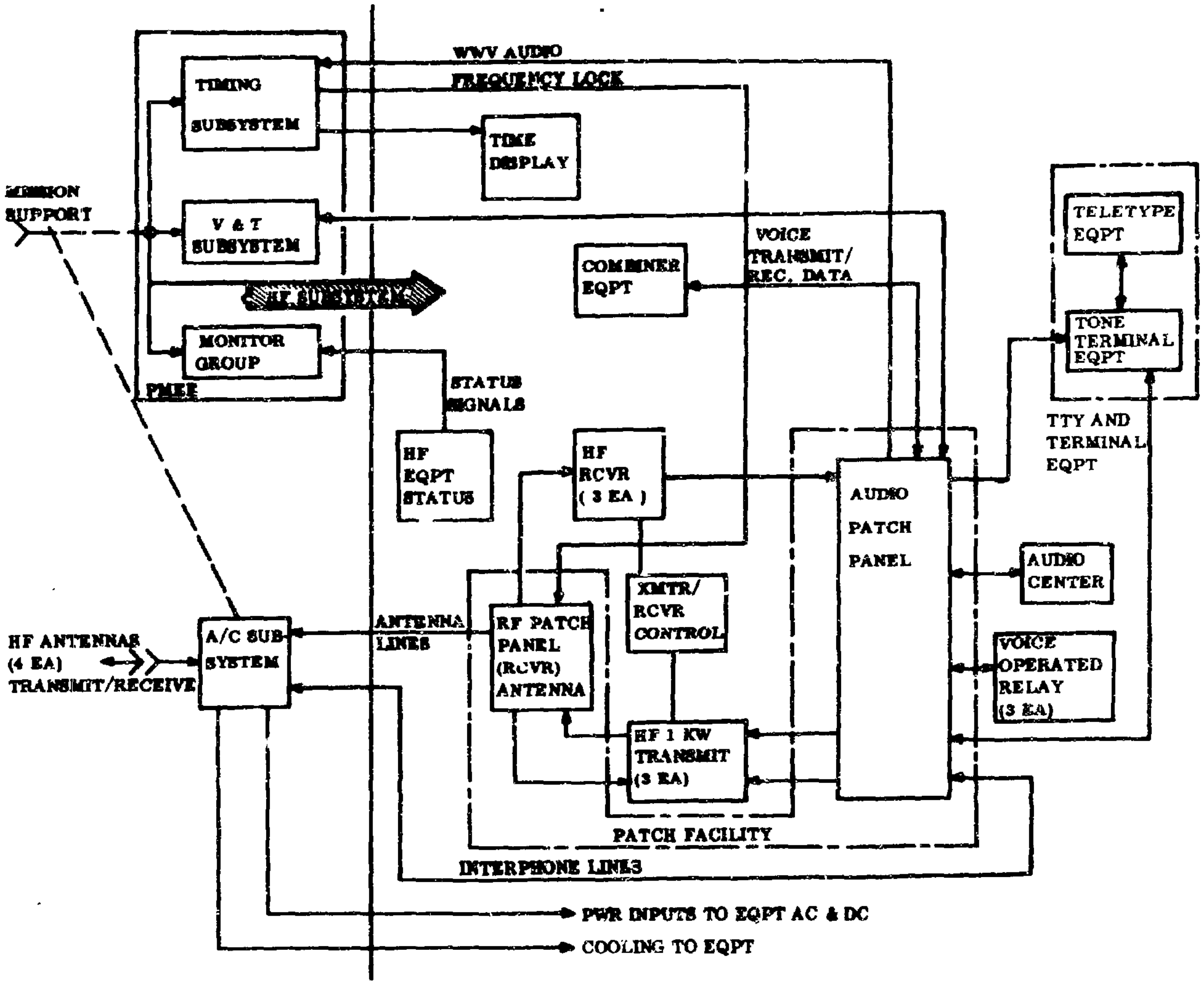


FIGURE I-9. HF SUBSYSTEM BLOCK DIAGRAM

HF Receiver

The HF receiver includes an IF translator and the RF translator, which are virtually identical to their respective counterparts in the transmitter.

a. RF Translator. The RF translator, also used in the HF transmitter, is essentially a bilateral converter. As a receiver, the input signal in the 2.0- to 29.9999-MHz range is translated to a 500-KHz output in the RF tuner, employing the identical injection frequencies used in up-conversion of the transmit mode. The 1-KHz tuning increment yields 28,000 receiver channels. Tuning to 0.1-KHz increments is further accomplished in the IF translator, subsequently described. The RF translator also supplies a 100-KHz reference standard to other units as required.

b. IF Translator. The IF translator accepts the 500-KHz IF from the RF translator, converts it to a 100-KHz IF and separates the multiplexed signals through five bandpass filters. Four of these filters channelize the information about 100 KHz while the fifth filter separates the carrier, to the degree it is present. The carrier channel is amplified and used to develop AGC and AFC control voltages, which are also used in a variety of signal monitor and alarm functions. The injection frequencies for the IF translator derive from 100-KHz standards supplied from the RF translator. Fine tuning resolution of 0.1-KHz steps is supplied in the IF translator, yielding a total of 280,000 tunable frequencies in the receiver.

HF Filters

Two types of filters are required in the HF system. A low-pass filter is required at the output of the transmitter power amplifier to attenuate out-of-band higher frequency emissions which might interfere with VHF equipment. A receiver pre-selection filter is necessary to negate the stronger transmitter levels which may be as close as 10-percent frequency spacing.

Antennas

The antenna complement of the HF communications subsystem is comprised of a trailing wire transmitting antenna, two wing-tip probe antennas which may be used for transmission or reception, and the use of the vertical fin-probe antenna, for backup in event of failure of a primary antenna.

Teletype Equipment

The teletype equipment is procured from the stock of vendors having current designs meeting the requirements of the A/RIA application. Specific items which meet the specifications of the terminal equipment are described subsequently.

a. Tone Telegraph Terminal. The frequency shift key tone telegraph terminal provides all equipment necessary for operating 16 complete transmitting and diversity receiving (duplex) channels with standard 170-Hz spacing or special 120-Hz channel spacing. The tone keyers are compatible with either 20- or 60-ma current loops with adjustable output level between -30 dBm and 0 dBm. The tone converters have a sensitivity range of -45 dBm to +5 dBm without line amplifier.

b. Keyboard Send/Receive Unit. The keyboard send/receive (KSR) unit provides page-printed copy from received format 7.42 at speeds of 60, 75, and 100 words per minute. Speed selection for send and receive functions is accomplished by a 3-speed gear selector.

c. Tape Transmitter/Distributor. The tape reader automatically reads and transmits tape information from 5-, 6-, 7-, or 8-level standard codes. The reader will function on all standard speeds up to 100 words per minute after simple gear changes.

d. Typing Reperforator. The typing tape punch is a receive-only machine designed as a 5-level reperforator. The unit operates at speeds of 60, 75, or 100 words per minute by a gear shift which permits instant switching.

Audio Facilities

Audio facilities include the following active elements: audio center, HF voice monitor facility, and audio combiners.

a. Audio Center. The audio center contains the interconnecting and level adjusting equipment, thus providing a monitoring control for all voice switching and relay circuits within the aircraft. In particular, the audio center accepts outputs from the HF up-link and the VHF and UHF down-link receivers. These signals will be distributed to the inputs of the VHF and UHF up-link and dual-HF down-link transmitters. The audio center also provides the necessary interface signal processing and control functions. The audio center includes matching facilities for all the interconnection options as well as for the processing equipment, including amplifiers and attenuators. Monitoring facilities consist of audio signal level (VU) meters. Amplification is provided by a series of single-channel, solid-state buffer amplifiers, furnishing 0-dBm signal levels at 600-ohm balanced impedance to the intercom system, recorders, and the spacecraft/ground communications equipment.

b. HF Voice Monitor Facility. The HF voice monitor facility accommodates the function of selecting, for aural evaluation, the several HF receiver sideband outputs. These outputs are coupled from the audio patch panel to the HF voice monitor, where any sideband channel may be selected by a bridging amplifier and amplified to a suitable listening level for evaluation by the HF Communications Subsystem Operator.

c. Audio Combiners. The audio combiners sum the relative signal plus noise appearing at the baseband outputs of the two receivers.

Master Control Console

The function of the master control console is to provide control, monitoring, and verbal communication capabilities within the A/RIA aircraft, and will provide the RF links to the spacecraft, ground, and other aircraft of the A/RIA fleet. The master control console contains illuminated indicators on the front panel to provide status information regarding other subsystems. In addition, illuminated alternate action switches are utilized on the front panel for control functions. Digital displays of Greenwich Mean Time, Countdown/Mission Elapsed Time, and aircraft position are provided. Tracking antenna azimuth and elevation indicators are provided on the console.

The console contains an intercom station, power controls, provisions for emergency oxygen, cooling air, hard-hat stowage, an ashtray, and cup holder. Two 28-volt power supplies are provided; the chassis includes circuitry which is used to flash indicators OFF and ON and to indicate failures of subsystem equipment.

The various types of indicators on the console front panel are grouped according to the subsystem to which they pertain; i. e., antenna control, air-to-ground, air-to-spacecraft, timing, and telemetry recording.

The console contains GO/NO-GO indication of each subsystem status. These are based on results of checkout procedures.

Figure I-10 shows a block diagram of the master control console.

A/RIA Test Instrumentation

Test instrumentation encompasses the on-board equipment comprised of test equipment peculiar to each of the subsystems and contained therein. In addition, portable test instruments are provided for in-flight unscheduled maintenance; they may be utilized at any of the operator positions. These portable test instruments will be used for fault isolation of the PMEE in flight during periods of deployment, for mission data interval coverage. In-flight maintenance will be limited to the removal and replacement of modules. Repair of the modules will be deferred to the operating base whenever possible.

In the event of a detected malfunction or suspect item of the PMEE, its redundant hot standby will immediately be patched in its place. Where redundant selection is not obtainable and as time permits, the problem will be isolated to the lowest replaceable unit of the particular system using the in-flight test equipment provided.

The in-flight test equipment is stowed aboard each of the eight A/RIA and is readily available for use while the A/RIA System is in flight.

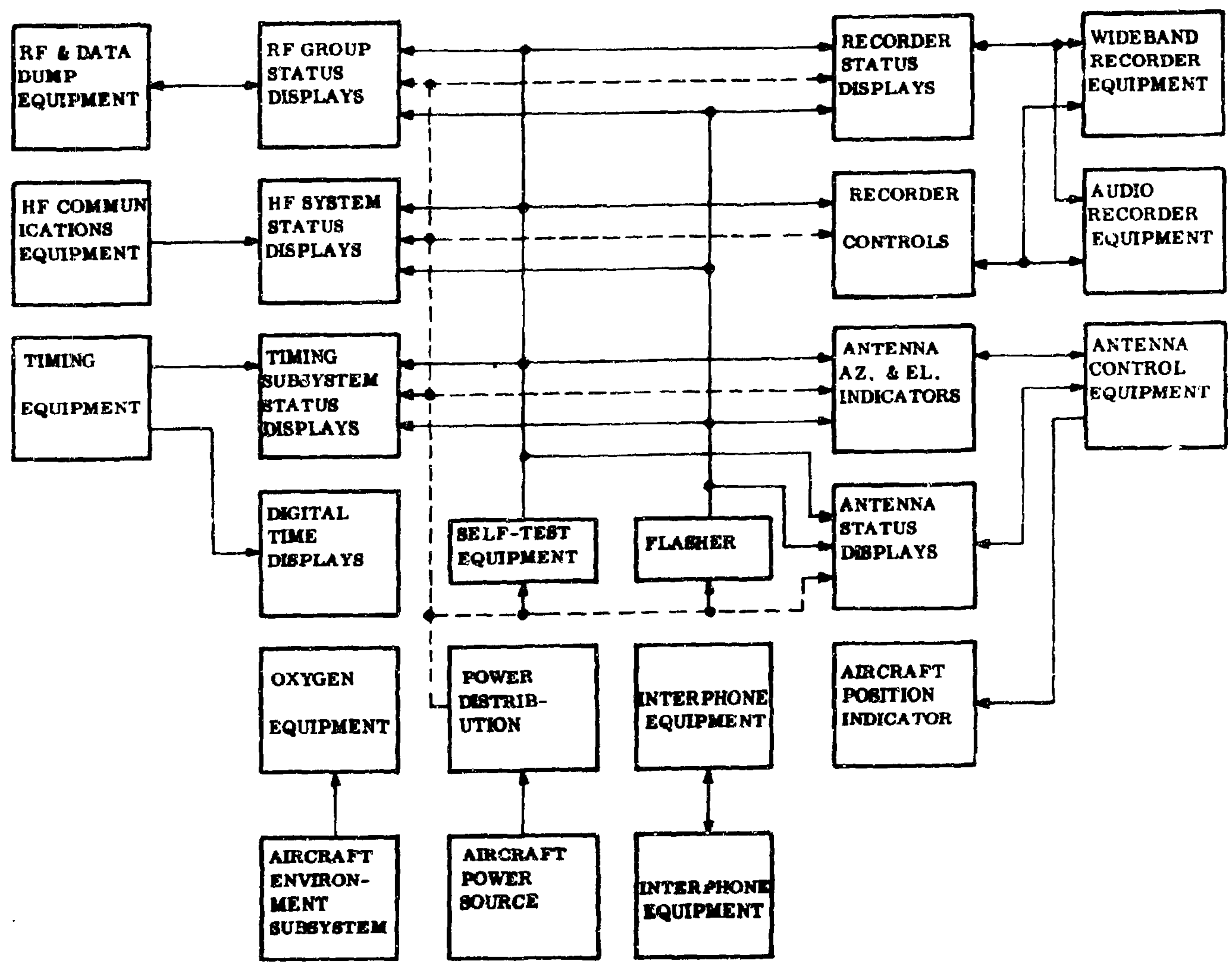


FIGURE I-10. MASTER CONTROL CONSOLE BLOCK DIAGRAM

Following is a list of in-flight test equipment:

a. Oscilloscope, Hewlett-Packard Model 140A.

b. Dual-Trace Amplifier, Plug-In, Hewlett-Packard Model 1402A.

c. Time-base/Delay Generator, Hewlett-Packard Model 1421A.

d. Multimeter, AN/PSM-6.

e. Crystal Detector, Hewlett-Packard Model 420B, or equivalent.

f. VHF/UHF Counter, Hewlett-Packard Model 5254L.

PMEE Operations Area

The PMEE operations area are functionally composed of equipment cabinets and console positions in configuration for the A/RIA aircraft (see Figure I-11).

Six operator console positions are provided as follows:

a. No. 1 - Mission Coordinator

b. No. 2 - Timing/Recorder Operator

c. No. 3 - Antenna Controller

d. No. 4 - Telemetry Operator

e. No. 5 - Spacecraft Communications Operators

f. No. 6 - HF Communications Operator

Operator mission functions and location areas are delineated in Table I-1 and in Figures I-5 and I-11.

CONFIGURATION CHANGES

The Category II Flight Test Program (and the Category I Qualification and Integration Tests conducted simultaneously with the Category II Program) revealed equipment and system problems, some of which are unresolved at the time of the preparation of this report. The complete listing of such problems is currently under study by ESD, Douglas Aircraft, and Bendix Radio Division, all of whom participated in the preparation of the list of problems outstanding at the completion of the Category II Test Program.

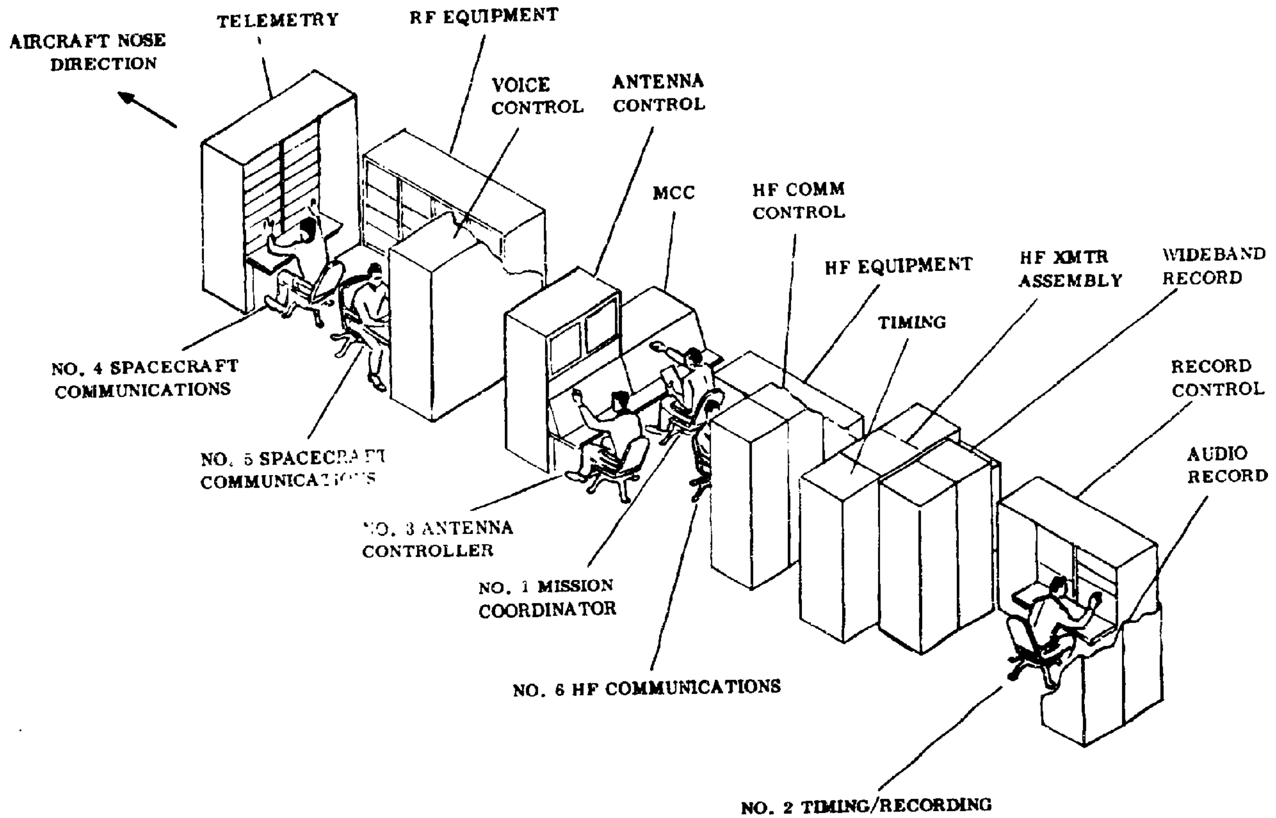


FIGURE I-11. PMEE CONFIGURATION LAYOUT

TABLE I-1

PMEE Crew Functions

Name*	Station	Operational Readiness	Pre-Flight	Mission
Mission Coordinator	750	Checks operational status of all subsystems and personnel.	Assures continued operational status of A/RIA subsystems.	Follows mission plan. Monitors status of all PMEE subsystems.
Timing/ Recording Operator	1000	Performs tests and determines readiness of Timing/ Recording Subsystem. Installs patch panels	Assures continued operational status of Timing/ Recording equipment.	Follows mission plan. Updates time standard. Monitors time status. Records all transmissions.
Antenna Control Operator	750	Performs tests and determines readiness of tracking antenna and antenna programmer.	Assures continued operational status of antenna control subsystem.	Inserts prelaunch data into programmer and operates tracking subsystem.
Spacecraft Communications Operator	600	Performs tests and determines readiness of spacecraft communications subsystem.	Assures continued operational status of voice and telemetry subsystems.	Operates voice and telemetry subsystems.
Ground Communications Operator	800	Performs tests and determines readiness of HF transmitters, HF receivers, and teletype.	Assures continued operational status of HF transmitters, HF receivers and teletype.	Operates HF transmitters, HF receivers, and teletype.

* Refer to Plan View - Operator's Locations

APPENDIX II

TEST INSTRUMENTATION

LIST OF ILLUSTRATIONS

LIST OF TABLES

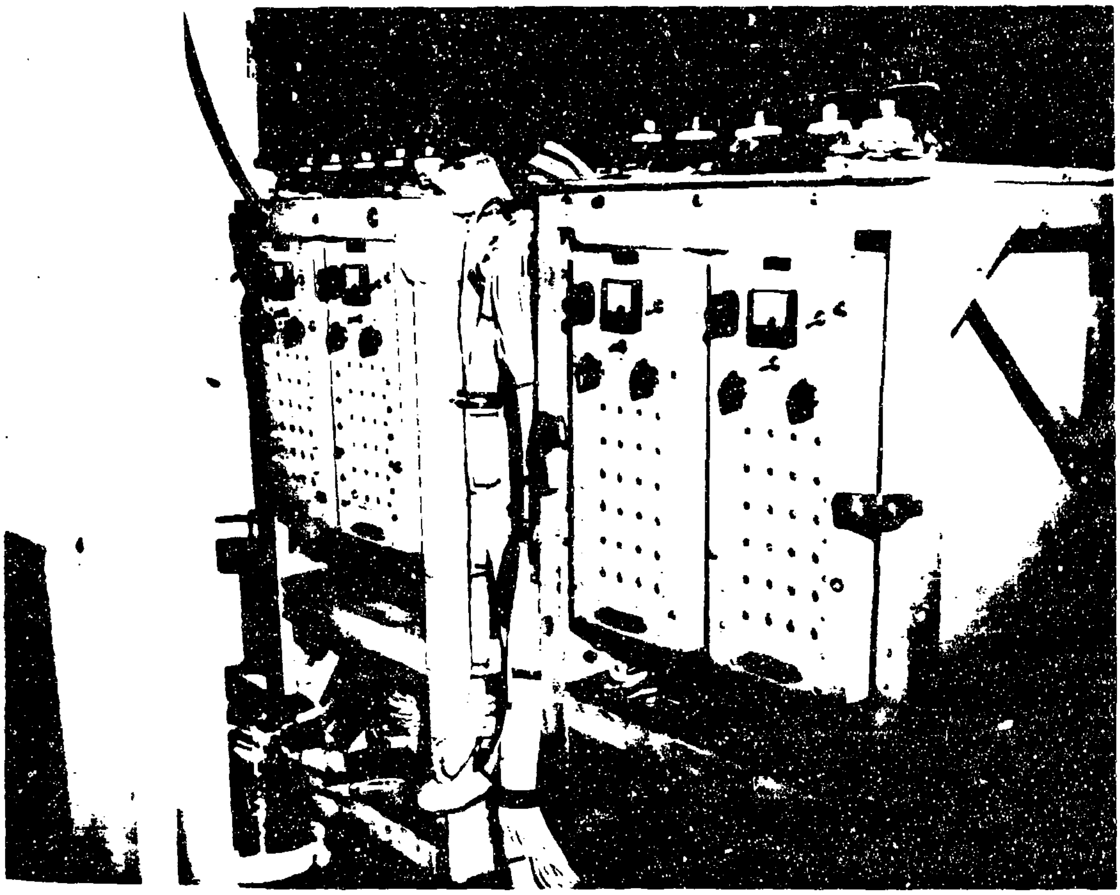


FIGURE II-1. OSCILLOGRAPH SIGNAL CONDITIONING UNITS

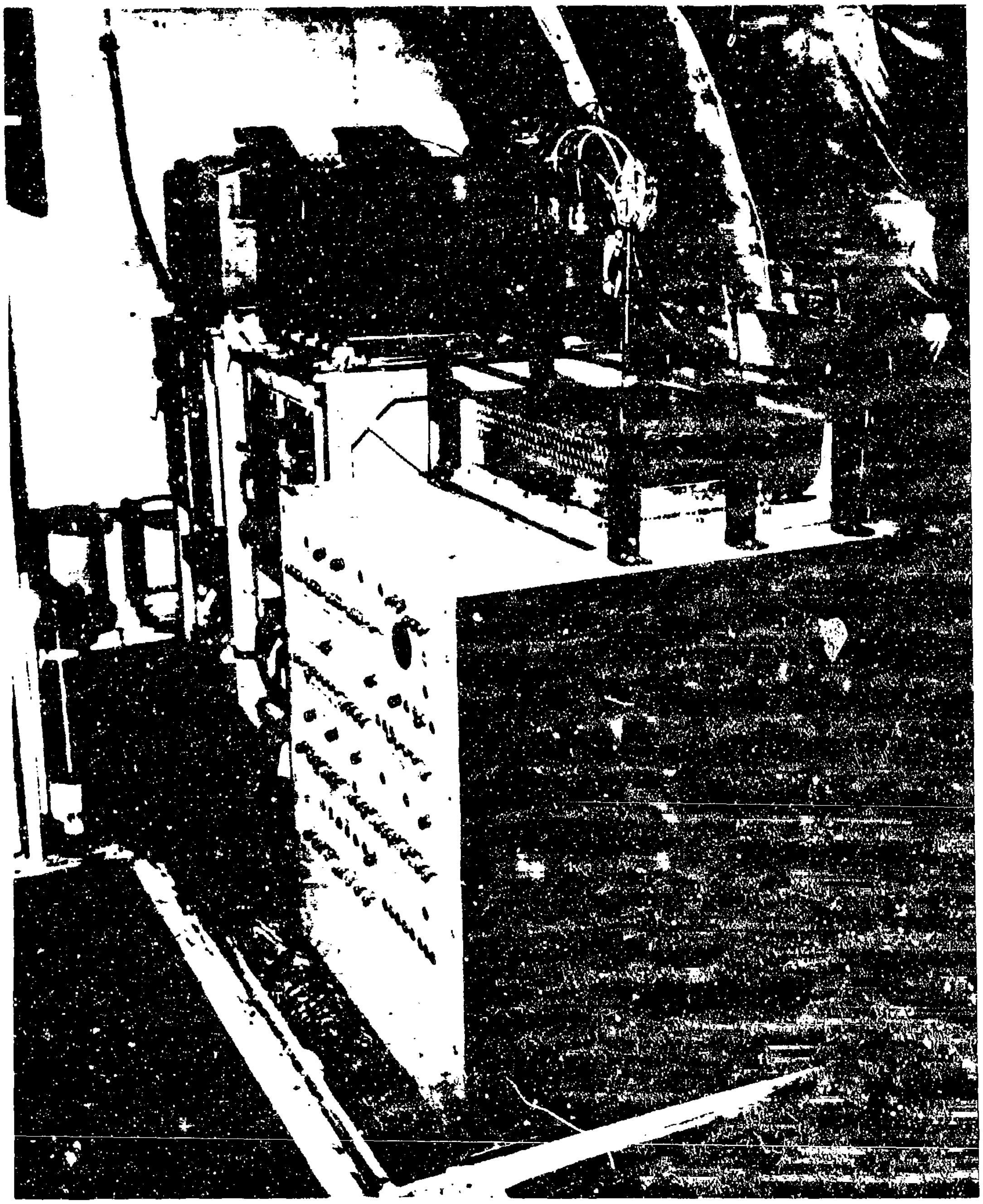


FIGURE II-2. OSCILLOGRAPH RECORDERS

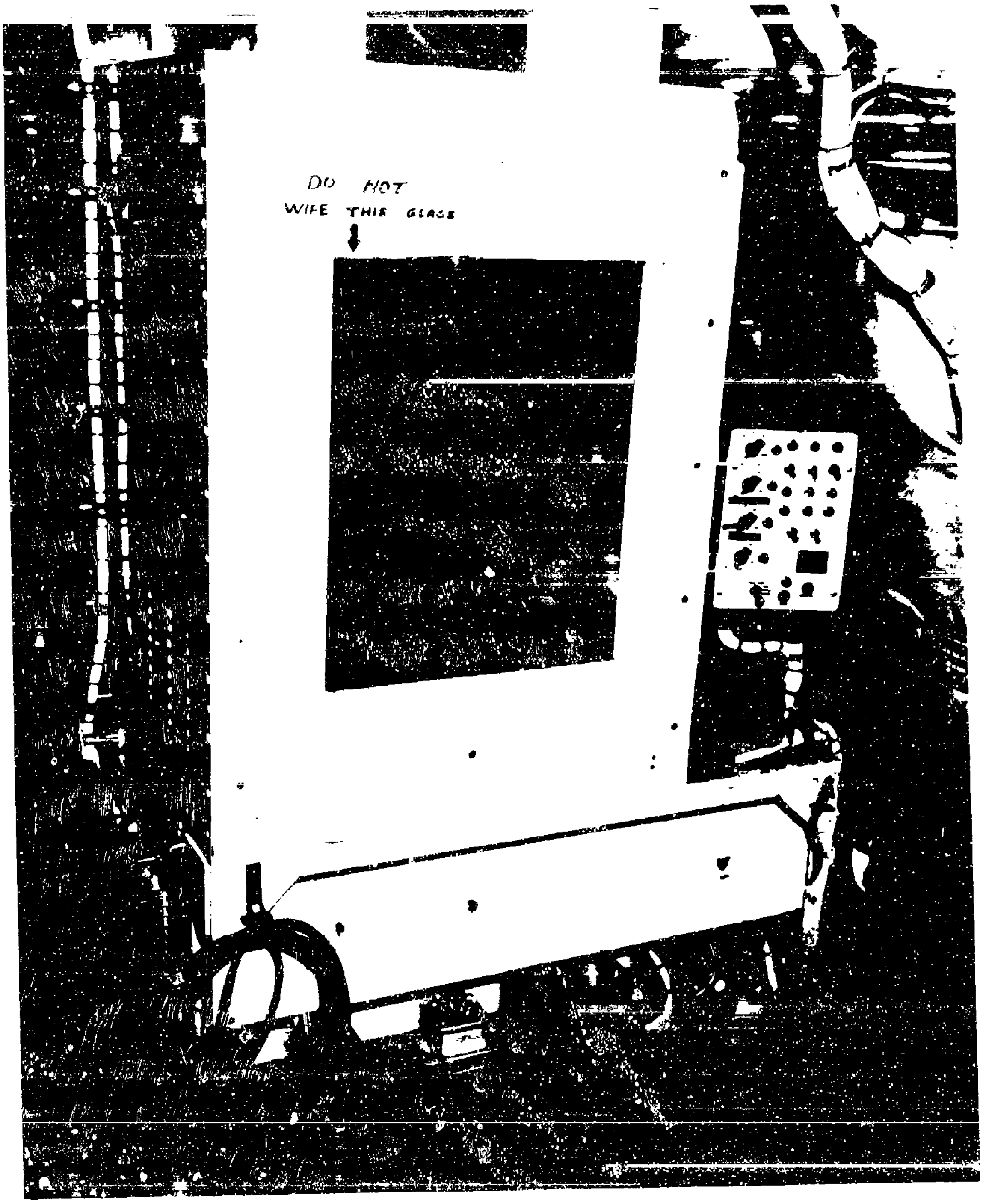


FIGURE II-3. PHOTO RECORDER

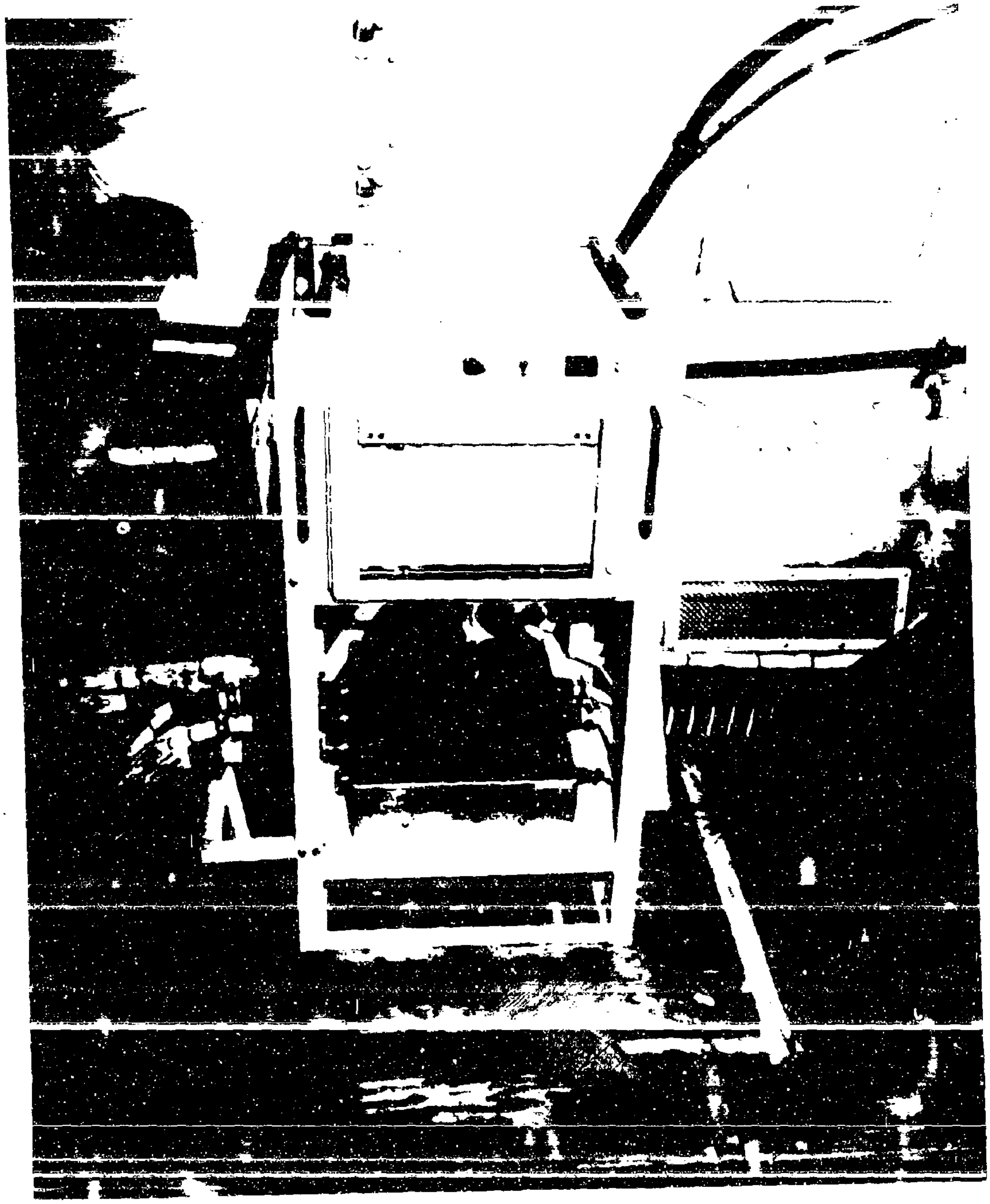
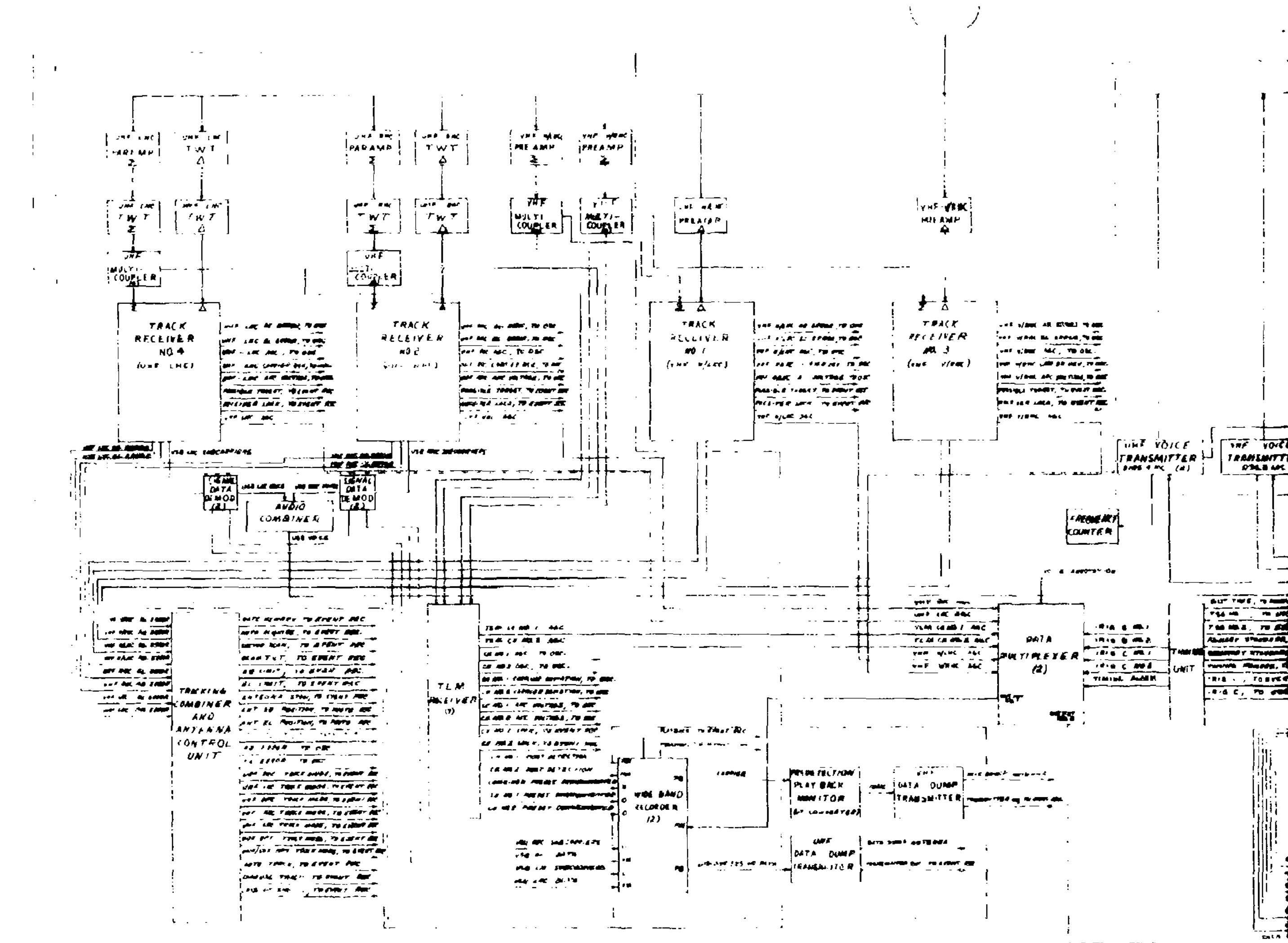


FIGURE II 4. EVENT RECORDER



PARAMP
TWT
PREAMP
MULTI COUPLER
TRACK RECEIVER NO 4
TRACK RECEIVER NO 2
TRACK RECEIVER NO 1
TRACK RECEIVER NO 3
AUDIO COMBINER
TRACKING COMBINER AND ANTENNA CONTROL UNIT
TLM RECEIVER
DATA MULTIPLEXER (2)
WIDE BAND RECORDER (2)
DATA DUMP TRANSMITTER
UHF VOICE TRANSMITTER
FREQUENCY COUNTER

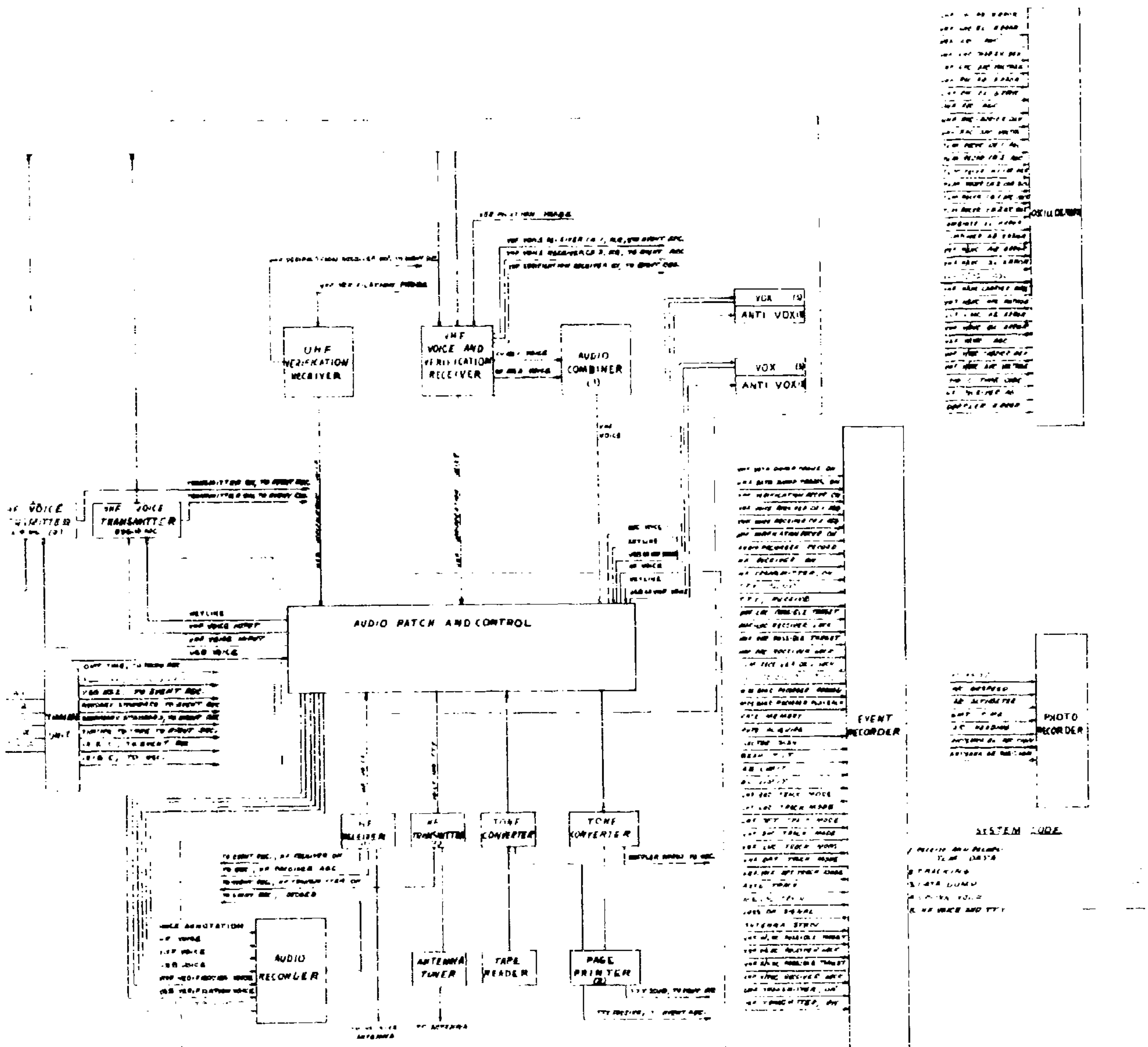


FIGURE II-5. PMEE AND INSTRUMENTATION INTERFACE

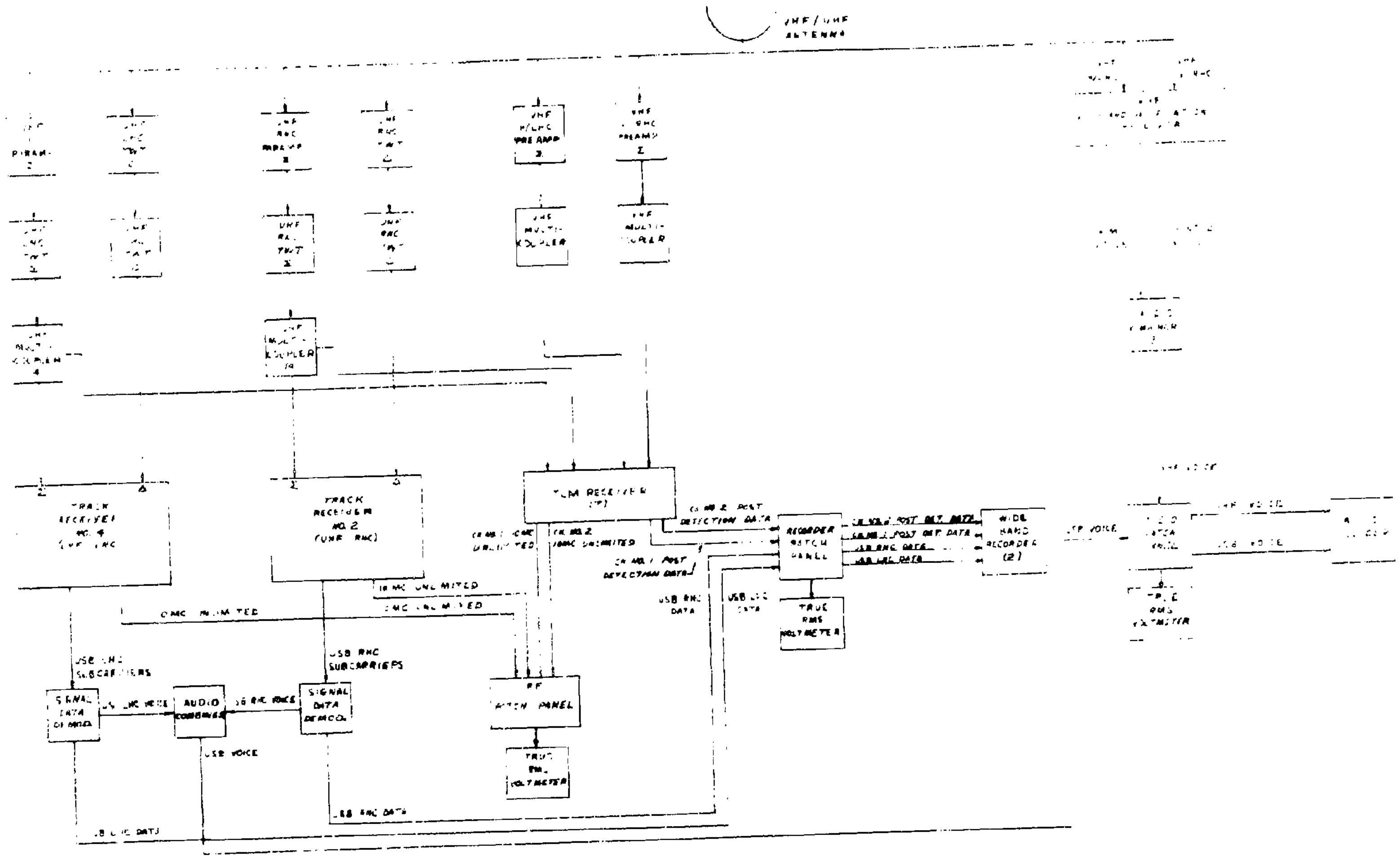


FIGURE II-6. PMEE AND INSTRUMENTATION FOR CNR AND SNR

TABLE II-1

PMEE Instrumentation Parameters Recorded on Oscillograph

Item No.	Function Recorded	Monitor Point	Impedance of Recording Channel (Ohms)	Flat Freq. Resp. (Hz)
1	TLM RCVR 1A AGC	OA-3	200K ± 100K	30
2	TLM RCVR 1A Carr. Freq.	OA-3	150K ± 100K	135
3	TLM RCVR 1A Carr. Dev.	OA-3	233K ± 100K	135
4	TLM RCVR 1B AGC	OA-3	200K ± 100K	30
5	TLM RCVR 1B Carr. Freq.	OA-3	150K ± 100K	135
6	TLM RCVR 1B Carr. Dev.	OA-3	233K ± 100K	135
7	TLM RCVR 2A AGC	OA-3	200K ± 100K	30
8	TLM RCVR 2A Carr. Freq.	OA-3	150K ± 100K	135
9	TLM RCVR 2A Carr. Dev.	OA-3	233K ± 100K	135
10	TLM RCVR 2B AGC	OA-3	200K ± 100K	30

TABLE B-1 (Continued)

Item No.	Function Recorded	Monitor Point	Impedance of Recording Channel (Ohms)	Flat Freq. Resp. (Hz)
11	TLM RCVR 2B Carr. Freq.	OA-3	150 ± 100K	135
12	TLM RCVR 2B Carr. Dev.	OA-3	233 ± 100K	135
13	TLM RCVR 3A AGC	OA-3	200K ± 100K	30
14	TLM RCVR 3A Carr. Freq.	OA-3	150K ± 100K	135
15	TLM RCVR 3A Carr. Dev.	OA-3	233K ± 100K	135
16	TLM RCVR 3B AGC	OA-3	200K ± 100K	30
17	TLM RCVR 3B Carr. Freq.	OA-3	150K ± 100K	135
18	TLM RCVR 3B Carr. Dev.	OA-3	233K ± 100K	135
19	TLM RCVR 4A AGC	OA-3	200K ± 100K	6
20	TLM RCVR 4A Carr. Freq.	OA-3	150K ± 100K	135
21	TLM RCVR 4A Carr. Dev.	OA-3	233K ± 100K	135

TABLE II-1 (Continued)

Item No.	Function Recorded	Monitor Point	Impedance of Recording Channel (Ohms)	Flat Freq. Resp. (Hz)
22	TLM RCVR 4B AGC	OA-3	200K ± 100K	6
23	TLM RCVR 4B Carr. Freq.	OA-3	150K ± 100K	135
24	TLM RCVR 4B Carr. Dev.	OA-3	233K ± 100K	135
25	TLM RCVR 5A AGC	OA-3	200K ± 100K	6
26	TLM RCVR 5A Carr. Freq.	OA-3	150K ± 100K	135
27	TLM RCVR 5A Carr. Dev.	OA-3	233K ± 100K	135
28	TLM RCVR 5B AGC	OA-3	200K ± 100K	6
29	TLM RCVR 5B Carr. Freq.	OA-3	150K ± 100K	135
30	TLM RCVR 5B Carr. Dev.	OA-3	233K ± 100K	135
31	TLM RCVR 6A AGC	OA-3	200K ± 100K	6
32	TLM RCVR 6A	OA-3	150K ± 100K	135

TABLE II-1 (Continued)

Item No.	Function Recorded	Monitor Point	Impedance of Recording Channel (Ohms)	Flat Freq. Resp. (Hz)
33	TLM RCVR 6A Carr. Dev.	OA-3	233K ± 100K	135
34	TLM RCVR 6B AGC	OA-3	200K ± 100K	6
35	TLM RCVR 6B Carr. Dev.	OA-3	150K ± 100K	135
36	TLM RCVR 6B Carr. Dev.	OA-3	233K ± 100K	135
37	TLM RCVR 7A AGC	OA-3	200K ± 100K	6
38	TLM RCVR 7A Carr. Freq.	OA-3	150K ± 100K	135
39	TLM RCVR 7A Carr. Dev.	OA-3	233K ± 100K	135
40	TLM RCVR 7B AGC	OA-3	200K ± 100K	6
41	TLM RCVR 7B Carr. Freq.	OA-3	150K ± 100K	135
42	TLM RCVR 7B Carr. Dev.	OA-3	233K ± 100K	135
43	H. F. RCVR 2 AGC	OA-5	233K ± 100K	135

TABLE II-1 (Continued)

Item No.	Function Recorded	Monitor Point	Impedance of Recording Channel (Ohms)	Flat Freq. Resp. (Hz)
[illegible]	TRK. RCVR 4 EL Error	OA-5	233K ± 100K	135
45	EL. TRK. ERROR	OA-5	233K ± 100K	135
46	AZ. TRK. ERROR	OA-5	233K ± 100K	135
47	TRK. RCVR 1 Carr. Freq.	OA-5	150K ± 100K	135
[illegible]	TRK. RCVR 2 Carr. Freq.	OA-5	150K ± 100K	135
49	TRK. RCVR 3 Carr. Freq.	OA-5	150K ± 100K	135
[illegible]	TRK. RCVR 4 Carr. Freq.	OA-5	150K ± 100K	135
53	TRK. RCVR 1 AZ. Error	OA-11	448K ± 100K	135
54	TRK. RCVR 1 AGC	OA-11	200K ± 100K	30
55	TRK. RCVR 1 EL. Error	OA-11	448K ± 100K	135
56	TRK. RCVR 2 AZ. Error	OA-11	448K ± 100K	135
57	TRK. RCVR 2	OA-11	200K ± 100K	30

TABLE II-1 (Continued)

Item No.	Function Recorded	Monitor Point	Impedance of Recording Channel (Ohms)	Flat Freq. Resp. (Hz)
58	TRK. RCVR 2 EL. Error	OA-11	448K ± 100K	135
59	TRK. RCVR 3 AS. Error	OA-11	448K ± 100K	135
60	TRK. RCVR 3 AGC	OA-11	200K ± 100K	30
61	TRK. RCVR 3 EL. Error	OA-11	448K ± 100K	135
62	TRK. RCVR 4 AZ Err...	OA-11	448K ± 100K	135
63	TRK. RCVR 4 AGC	OA-11	200K ± 100K	30
64	TRK. RCVR 4 EL. Error	OA-11	448K ± 100K	135
65	TTY DOPPLER	OA-14	175K ± 100K	135
66	H. F. RCVR 1 AGC	OA-16	734K ± 100K	30
67	H. F. RCVR 2 AGC	OA-16	734K ± 100K	30
68	H. F. RCVR 3 AGC	OA-16	734K ± 100K	30
69	SERIAL TIME CODE	OA-18	1.53m ± 100K	135

TABLE II-2

PMEE Instrumentation Parameters
(Event Recorder)

Item	Function	Monitor Point	Switching Mode
1	POSSIBLE TARGET	OA-11	RELAY
2	UHF OPT	OA-11	RELAY
3	UHF/VHF OPT	OA-11	RELAY
4	VHF OPT	OA-11	RELAY
5	VHF RHC	OA-11	RELAY
6	VHF LHC	OA-11	RELAY
7	UHF RHC	OA-11	RELAY
8	UHF LHC	OA-11	RELAY
9	AUTO TRACK	OA-11	RELAY
10	MANUAL TRACK	OA-11	RELAY
11	LOSS OF SIGNAL	OA-11	RELAY
12	Az LIMIT	OA-11	RELAY
13	E LIMIT	OA-11	RELAY
14	RATE MEMORY	OA-11	RELAY
15	ANTENNA STOW	OA-11	RELAY
16	SECTOR SCAN	OA-11	RELAY
17	DATA RCVR 1A ACQ	OA-12	TRANS
18	DATA RCVR 1B ACQ	OA-12	TRANS
19	DATA RCVR 2A ACQ	OA-12	TRANS
20	DATA RCVR 2B ACQ	OA-12	TRANS
21	DATA RCVR 3A ACQ	OA-12	TRANS
22	DATA RCVR 3B ACQ	OA-12	TRANS
23	DATA RCVR 4A ACQ	OA-12	TRANS
24	DATA RCVR 4B ACQ	OA-12	TRANS
25	DATA RCVR 5A ACQ	OA-12	TRANS
26	DATA RCVR 5B ACQ	OA-12	TRANS
27	DATA RCVR 6A ACQ	OA-12	TRANS
28	DATA RCVR 6B ACQ	OA-12	TRANS
29	DATA RCVR 7A ACQ	OA-12	TRANS
30	DATA RCVR 7B ACQ	OA-12	TRANS
31	UHF VERIF RCVR ON	OA-12	TRANS
32	VHF VERIF RCVR ON	OA-12	TRANS
33	VHF VOICE RCVR 1A ACQ	OA-12	TRANS
34	VHF VOICE RCVR 1B ACQ	OA-12	TRANS
35	VHF TRANSMITTER ON	OA-12	TRANS
36	UHF TRANSMITTER #1 ON	OA-12	TRANS
37	UHF TRANSMITTER #2 ON	OA-12	TRANS
38	VHF DATA DUMP TRANS ON	OA-12	TRANS
39	UHF DATA DUMP TRANS ON	OA-12	TRANS

TABLE II-2 (Continued)

Item	Function	Monitor Point	Switching Mode
40	TRK RCVR #1 ACQ	OA-12	TRANS
41	TRK RCVR #2 ACQ	OA-12	TRANS
42	TRK RCVR #3 ACQ	OA-12	TRANS
43	TRK RCVR #4 ACQ	OA-12	TRANS
44	AUDIO RECORDER RECORD	OA-12	TRANS
45	WIDEBAND RECORDER #1 RECORD	OA-12	TRANS
46	WIDEBAND RECORDER #2 RECORD	OA-12	TRANS
47	WIDEBAND RECORDER #1 PLAYBACK	OA-12	TRANS
48	WIDEBAND RECORDER #2 PLAYBACK	OA-12	TRANS
49	HF RCVR #1 ON	OA-12	TRANS
50	HF RCVR #2 ON	OA-12	TRANS
51	HF RCVR #3 ON	OA-12	TRANS
52	HF TRANS #1 ON	OA-12	TRANS
53	HF TRANS #2 ON	OA-12	TRANS
54	HF TRANS #3 ON	OA-12	TRANS
55	TTY #1 SEND	OA-12	TRANS
56	TTY #2 SEND	OA-12	TRANS
57	TTY #2 RECEIVE	OA-12	TRANS
58	TTY #2 RECEIVE	OA-12	TRANS
59	TSG #1	OA-12	TRANS
60	TSG #2	OA-12	TRANS
61	PRIMARY STANDARD	OA-12	TRANS
62	SECONDARY STANDARD	OA-12	TRANS
63	TIMING FAILURE	OA-12	TRANS
64	IRIG C TIME CODE	OA-18	RELAY

APPENDIX III

TECHNICAL DATA

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TYPICAL LINK ANALYSIS

Link Analysis for Flight #15, A/RIA 372

$P_{dc} = (P_t - L_t) + G_t - L_s - L_o + G_T - L_y$

P_{dc} = Power at the aircraft directional coupler in dBm

P_t = Transmitter power in dBm

L_t = Loss between transmitter and antenna in dBm

G_t = Transmitter antenna gain in dBm

L_s = Space Loss = 37.8 + 20 log (f_{MHz} + 20 log (R_{NM})

L_o = Polarization Loss = 4.1 dB (linear to circular)

G_T = Gain of receiving antenna

L_y = Loss in receiver system to directional coupler

<u>USB</u>

P_{dc} = -115.6 for 1.6 kbs data and voice

= -105.5 for 51.2 kbs data (marginal signal)

= -90.5 for 51.2 kbs data (favorable signal)

P_t =

L_t = -5.1 dBm

G_t = 16.0 dBm

L_s = 37.8 + 20 log (2287.5) + 20 log (70)

= -(37.8 + 67.234 + 36.9)

= -141.9 dBm

L_o = -4.1 dBm

G_T = 30.6 dBm

L_y = -2.1 dBm

<u>USB 1.6 kbs Data</u>

-115.6 = P_t - 5.1 + 16 - 141.9 - 4.1 + 30.6 - 2.1

-115.6 = P_t - 153.2 + 46.6

$-P_t$ = 115.6 - 153.2 + 46.6

P_t = -115.6 + 153.2 - 46.6

P_t = 153.2 - 162.2

P_t = -9.0 dBm at ground station patch panel

<u>USB 51.2 kbs Data</u> (marginal signal)

-105.5 = P_t - 5.1 + 16 - 141.9 - 4.1 + 30.6 - 2.1

-105.5 = P_t - 153.2 + 46.6

$-P_t$ = 105.5 - 153.2 + 46.6

P_t = -105.5 + 153.2 - 46.6

P_t = 153.2 - 152.1

P_t = 1.1 dBm at ground station patch panel

<u>USB 51.2 kbs Data</u> (favorable signal)

-90.5 = P_t - 5.1 + 16 - 141.9 - 4.1 + 30.6 - 2.1

-90.5 = P_t - 153.2 + 46.6

$-P_t = 90.5 - 153.2 + 46.6$
$P_t = -90.5 + 153.2 - 46.6$
$P_t = 16.1$ dBm at ground station patch panel.

VHF

$P_{dc} = -106.5$ for 1.6 kbs and 51.2 kbs data (marginal signal)
-112.5 for voice
-91.5 for 1.6 kbs and 51.2 kbs data (favorable signal)

$P_t =$
$L_t = -2.3$ dBm
$G_t = 10$ dBm at 237.8 MHz (VHF tracking and data)
$= 10.8$ dBm at 296.8 MHz (VHF voice)
L_s = Space Loss $= 37.8 + 20 \log (f_{MHz}) + 20 \log (d_{NM})$
$= -(37.8 + 47.6 + 36.9)$
$= -122.3$ dBm tracking and data (237.8 MHz)

$= -(37.8 + 49.5 + 36.9)$
$= -124.2$ dBm Voice (296.8 MHz)

$L_o = -4.1$ dBm
$G_t = 13$ dBm
$L_v = -1.9$ dBm

VHF 1.6 kbs and 51.2 kbs Data (Marginal Signal)

$-106.5 = P_t - 2.3 + 10 - 122.3 - 4.1 + 13 - 1.9$
$-106.5 = P_t - 130.6 + 23$
$-P_t = 106.5 - 130.6 + 23$
$P_t = -106.5 + 130.6 - 23$
$P_t = 130.6 - 129.5$
$P_t = 1.1$ dBm at ground station patch panel

VHF Voice

$-112.5 = P_t - 2.3 + 10.8 - 124.2 - 4.1 + 13 - 1.9$
$-112.5 = P_t - 132.5 + 23.8$
$-P_t = 112.5 - 132.5 + 23.8$
$P_t = -112.5 + 132.5 - 23.8$
$P_t = 132.5 - 136.3$
$P_t = -3.8$ dBm at ground station patch panel

VHF 1.6 kbs and 51.2 kbs data (Favorable Signal)

$-91.5 = P_t - 2.3 + 10 - 122.3 - 4.1 + 13 - 1.9$
$-91.5 = P_t - 130.6 + 23$
$-P_t = 91.5 - 130.6 + 23$
$P_t = -91.5 + 130.6 - 23$
$P_t = 130.6 - 114.5$
$P_t = 16.1$ dBm at ground station patch panel

USB

1.6 kbs data = -115.6 dBm = 3.0×10^{-15} w/m^2

51.2 kbs data and voice (marginal signal) = -10[illegible]$.5$ dBm = 2.4×10^{-14} w/m^2

51.2 kbs data (favorable signal) = -90.5 dBm = 7.5×10^{-13} w/m^2

VHF

Voice = -112.5 dBm = 5.4×10^{-15} w/m^2

1.6 kbs and 51.2 kbs data (marginal signal) = -106.5 dBm = 1.1×10^{-14} w/m^2

1.6 kbs and 51.2 kbs data (favorable signal) = -91.5 dBm = 3.5×10^{-13} w/m^2

TYPICAL PMEE FLIGHT PLAN

Flight 15, A/RIA 372, PMEE Operations

This flight is planned to verify and take data concerning the following paragraphs of Section 7 of Category II Test Procedure DAC 56171, Volume I of II.

Procedure Paragraph	Function
7.3.1.C.10	Initial VHF Acquisition and Track, switch to UHF Track (Favorable)
7.4.1.C.1	Acq. and Track UHF/RHC, SS/AA (Favorable)
7.4.1.C.2	Side Lobe Acq./Track Susceptibility at UHF
7.4.1.C.3	Acq. and Track UHF/RHC, SS/AA, switch to UHF/LHC, switch to UHF/OPT (marginal)
7.4.1.C.4	Memory Rate Tracking
7.4.1.C.5	VHF Beam Tilt
7.4.4.C.1	Azimuth Tracking Limits
7.4.4.C.2	Lower Elevation Tracking Limits
7.6.1.C.1	Receive VHF Voice (normal, and 1000 Hz tone at Apollo power levels)
7.6.1.C.2.b	Record VHF Voice, polarization combined (normal, and 1000 Hz tone at Apollo power levels)
7.6.2.C.1	Receive UHF Voice (1000 Hz tone)
7.6.2.C.2	Record UHF Voice (1000 Hz tone)
7.7.1.C	Transmit VHF Voice
7.9.1.C.1	Receive and Record Telemetry Data at UHF
7.9.1.C.1	Receive and Record VHF TLM Data
7.11.B.1	HF Receive
7.11.B.2	HF Transmit

Flight Patterns

1. RF Radiation Pattern 1 - Inbound from 150 nm to beyond first null.
2. Six standard racetracks.
3. RF Radiation Pattern 2 - Inbound from 150 nm to beyond lower elevation limit

RF Pattern Check 1 (Reference Paragraph 6.8)

1. Acquire and Track on UHF/RHC
2. Make on-board AGC readings from Data Receiver 3 or 4 and UHF Track Receiver 2 to detect pattern null.

Data Run 1

1. Acquire and Track at UHF with Sector Scan/Automatic Acquisition in a Favorable Signal Environment using Right Hand Circular (RHC) Polarization (Reference Paragraph 7.4.1.C.1). Acquire and Track: UHF/RHC

a. UHF Power Density at A/RIA Antenna: 7.6×10^{-13}

b. UHF Power at A/RIA Directional Coupler: -90.5 dBm w/m^2

c. Tracking Frequency: 2287.5 MHz, 51.2 KBPS data

d. VHF voice 1000 Hz tone Power Density at A/RIA antenna: 5.4×10^{-15} w/m^2

e. VHF voice 1000 Hz tone power at A/RIA Directional Coupler: -112.2 dBm

f. VHF voice frequency: 296.8 MHz

g. Sector Scan Parameters: Az Sector $\pm 4^{0}$ Sweep: 2
Az Rate 4^{0}/Sec E Incr: 3.2^{0}

2. Receive and Record VHF voice, Polarization Combined (Reference Paragraph 7.6.1.C.1 and 7.6.1.C.2.b).
3. Transmit VHF Voice (Reference Paragraph 7.7.1.C).
4. Receive and Record USB Telemetry Data (Reference Paragraph 7.9.3.C).
5. Receive HF Voice (Reference Paragraph 7.11.B.1).
6. Transmit HF Voice (Reference Paragraph 7.11.B.2).
7. Special Instrumentation to measure Carrier/Noise and Signal/Noise of received data.

Data Run 2

1. Side Lobe Acquisition/Tracking Susceptibility at UHF (Reference Paragraph 7.4.1.C.2) - Part 1

a. Acquire and Track: UHF/RHC, SS/AA

b. UHF Power Density at A/RIA Antenna: 7.6×10^{-13}

c. UHF Power at A/RIA Directional Coupler: -90.5 dBm

d. Tracking Frequency: 2287.5 MHz, 51.2 KBPS

e. VHF voice frequency: 296.8 MHz

f. Sector Scan Parameters: Az Sector $\pm 4^{0}$ Sweep: 2
Az Rate 4^{0}/Sec E Incr: 3.2^{0}

2. Receive and Record VHF Voice, Polarization Combined (Reference Paragraph 7.6.1.C.1 and 7.6.1.C.2.b).
3. Transmit VHF Voice (Reference Paragraph 7.7.1.C).
4. Receive HF Voice (Reference Paragraph 7.11.B.1).
5. Transmit HF Voice (Reference Paragraph 7.11.B.2).
6. Determine UHF Threshold (Reference Paragraph 7.4.1.C.2) - Part 1.

Data Run 3

1. Side Lobe Acquisition/Tracking Susceptibility at UHF (Reference Paragraph 7.4.1.C.2) - Part 2.

a. Acquire and Track (Sidelobe): UHF/RHC, SS/AA

b. UHF Power at A/RIA: 23 dB above threshold

c. Tracking frequency: 2287.5 MHz, 51.2 KBPS data

d. Sector Scan Parameters: Az Sector $\pm 4^{0}$ Sweep: 2
Az Rate 4^{0}/Sec E Incr: 3.2^{0}

2. Receive and Record VHF voice, Polarization Combined (Reference Paragraph 7.6.1.C.1 and 7.6.1.C.2.b).

3. Transmit VHF Voice (Reference Paragraph 7.7.1.C)
4. Receive HF Voice (Reference Paragraph 7.11.B.1)
5. Transmit HF Voice (Reference Paragraph 7.11.B.2).
6. Acquire and Track on Both UHF Sidelobes (Reference Paragraph 7.4.1.C.2) - Part 2.

Data Run 4

1. Acquire and Track UHF/RHC, SS/AA, switch to UHF/LHC, switch to UHF/OPT. Marginal signal level (Reference Paragraph 7.4.1.C.3).
   a. UHF Power Density at A/RIA antenna: 2.4×10^{-14}
   b. UHF Power at A/RIA Directional Coupler: -105.5 dBm
   c. VHF TLM power density at A/RIA antenna: 1.1×10^{-14}
   d. VHF TLM power at A/RIA Directional Coupler: -106.5 dBm
   e. VHF voice frequency: 296.8 MHz
   f. Tracking Frequency: 2287.5 MHz, 51.2 KBPS data
   g. Sector Scan Parameters: Az Sector $\pm 4^{\circ}$ Sweep: 2
      Az Rate 4°/Sec E Incr: 3.2°
2. Receive and Record VHF Voice, Polarization Combined (Reference Paragraph 7.6.1.C.1 and 7.6.1.C.2).
3. Transmit VHF Voice (Reference Paragraph 7.7.1.C).
4. Receive and Record VHF TLM data (Reference Paragraph 7.9.1.C.1).
5. Receive and Record UHF TLM data (Reference Paragraph 7.9.1.C.1).
6. Receive HF Voice (Reference Paragraph 7.11.B.1)
7. Transmit HF Voice (Reference Paragraph 7.11.B.2)
8. Special Instrumentation to measure Carrier/Noise and Signal/Noise of received data.

Data Run 5

1. Acquire and Track at UHF, with Sector Scan/Automatic Acquisition in a marginal Signal Environment using UHF/OPT, Perform Beam Tilt Test (Reference Paragraph 7.4.1.C.5).
   a. UHF Power Density at A/RIA Antenna 2.4×10^{-14}
   b. UHF Power at A/RIA Directional Coupler: -105.5 dBm
   c. VHF Power Density at A/RIA Antenna: 3.5×10^{-13}
   d. VHF Power at A/RIA Directional Coupler: -91.5 dBm
   e. VHF Voice Frequency: 296.8 MHz
   f. Tracking Frequency: 2287.5 MHz, 51.2 KBPS data SC
   g. 1000 Hz tone on USB Voice SC
   h. Sector Scan Parameters: Az Sector $\pm 4^{\circ}$ Sweep: 2
      Az Rate 4°/Sec E Incr: 3.2°
2. Receive and Record VHF Voice, Polarization Combined (Reference Paragraph 7.6.1.C.1 and 7.6.1.C.2.b).
3. Receive and Record USB Voice, Polarization Combined (Reference Paragraph 7.6.2.C.1 and 7.6.2.C.2).
4. Transmit VHF Voice (Reference Paragraph 7.7.1.C).
5. [illegible] (Reference Paragraph 7.4.1.C.5).

6. Receive and Record USB TLM data (Reference Paragraph 7.9.1.C.1)
7. Receive and Record VHF TLM data (Reference Paragraph 7.9.1.C.1)
8. Receive HF Voice (Reference Paragraph 7.11.B.1)
9. Transmit HF Voice (Reference Paragraph 7.11.B2)
10. Special Instrumentation to measure Carrier/Noise and Signal/Noise of received data.

Data Run 6

1. Initial VHF Acquire and Track, switch to UHF Track, Favorable Signal Environment, Manual Scan, Automatic Acquisition (Reference Paragraph 7.3.1.C.10).
   a. UHF Power Density at A/RIA antenna: 7.6×10^{-13}
   b. UHF Power at A/RIA Directional Coupler: -90.5 dBm
   c. VHF Power Density at A/RIA Antenna: 3.5×10^{-13}
   d. VHF Power at A/RIA Directional Coupler: -91.5 dBm
   e. VHF Voice frequency: 296.8 MHz
   f. Tracking Frequency: 2287.5 MHz 51.2 KBPS data

2. Receive and Record VHF Voice, Polarization Combined (Reference Paragraph 7.6.1.C.1 and 7.6.1.C.2.b).
3. Transmit VHF Voice (Reference Paragraph 7.7.1.C)
4. Receive and Record VHF TLM data (Reference Paragraph 7.9.1.C.1)
5. Receive HF Voice (Reference Paragraph 7.11.B.1)
6. Transmit HF Voice (Reference Paragraph 7.11.B.2)
7. Memory Rate Tracking (Reference Paragraph 7.4.1.C.4)
8. Special Instrumentation to measure Carrier/Noise and Signal/Noise of received data.

Radiation Pattern Check 2 (Reference Paragraph 6.8)

1. Acquire and Track on UHF/RHC.
2. Make on-board AGC readings from Data Receiver 2 or 4 and UHF Track Receiver 2 to detect pattern null.
3. Evaluate lower elevation limit (Reference Paragraph 7.4.4.C.2)

TYPICAL FLIGHT CARDS

FLIGHT CARD

A/RIA FLIGHT TEST PROGRAM

Test Data Run #6 VHF Acquisition

Altitudes 35,700 FEET

Airspeeds 390 KTAS

Card No. J

Test No. ____

ACFT No. 372

Flight No. 15

AIRCRAFT CONFIGURATION

Flaps UP Gear UP Weight N.A. C.G. N.A.

INSTRUMENTATION

P/R 2 SEC OSC HI SPEED CKPT CAM N.A. G/S CAM N.A.

PROCEDURE - FLIGHT CREW - FLY STANDARD RACETRACK

ITEM	DIRECTED BY	PERFORMED BY	TEST	FUNCTION
1	MCC	Record	Data Run 6	Load WB Recorder and annotate tape: A/RIA 372, Flight #15, Flight Card J. Acquisition and Tracking on VHF/UHF OPT. Initial VHF Acquisition with transfer to UHF Tracking. Favorable Signal Environment. HF and VHF Voice Comm. Receive and Record VHF TLM and VHF Voice Polarization combined. Measure UHF and VHF C/N and S/N. Perform Rate Memory.
		Record		Annotate audio recorder.
2		FTE		Notify Ground Station to prepare for data run ten minutes prior to acquisition.
		Ground		Prepare to transmit VHF and USB TLM data. Set UHF power level at directional coupler to -90.5. Set VHF power level at directional coupler to -91.5.
3	MCC	TLM/Voice		Measure noise level at 10 MHz unlimited output of UHF TRK receiver data channels. Record: TRK RCVR #2 ____ TRK RCVR #4 ____ GMT ____

AIRCRAFT # 372
FLIGHT # 15
FLIGHT CARD #

DATA RUN #6
VHF ACQ OPERATOR

DATE

ITEM	DIRECTED BY	PERFORMED BY	TEST	FUNCTION
4	MCC	Antenna		Set antenna scan parameters. Az Sector ±4° Az Rate 4°/Sec E Incr 3.2° E Steps 2
5		FTE		Notify MCC and Ground Station at Point 1 of Flight Pattern (two minutes prior to start of inbound turn).
		Ground Station		Radiate UJB without modulation. Radiate VHF without modulation.
6		FTE		Notify MCC and Ground Station at Point 2 of flight pattern (one minute prior to start of inbound turn).
	MCC	Antenna		Unstow antenna MAN TRK UHF/VHF OPT Track Mode Set antenna to: AZ 34° E + 4°
7	MCC	HF		Establish or maintain 2-way HF voice link.
8		FTE		Notify ground station and MCC at Point 3 on flight pattern (start of inbound turn).
		Navigator		Record Point 3 GMT________.
	MCC	FTE		Start oscillograph and event recorders.
	MCC	Antenna		Start acquisition, MS, AUTO ACQ. Record AUTO TRK GMT ________.
		Antenna		Observe VHF tracking brings target within the UHF scan width. Record UHF switchover. GMT________.

AIRCRAFT # 372 DATA RUN #6 DATE ______

FLIGHT # 15 VHF ACQ OPERATOR [illegible]

FLIGHT CARD # ______

ITEM	DIRECTED BY	PERFORMED BY	TEST	FUNCTION
9		Antenna		Announce: Stable Track
	MCC			Establish VHF Voice Link, notify Ground Station of Stable Track.
10	MCC	Record		Measure noise level USB baseband signal SDD 1 & 2 Record: GMT______ SDD #1______ SDD #2______
11		FTE		Notify Ground Station and MCC at Point 4 on flight pattern (on course, 120 NM from TULSA).
		Navigator		Record Point 4 GMT______
		Ground Station		Modulate USB TLM transmitter. Modulate VHF TLM transmitter.
12	MCC	Record		Start VB recorders.
		TLM/Record		Verify USB, VHF TLM data is being received. Check data quality.______
13		MCC		Give MARK at one minute intervals.
	MCC	Voice		Measure C/N level on MCC MARK at USB TRK RCVR data channel. Record: #1 GMT______ #3 GMT______ TRK RCVR #2______ TRK RCVR #2______ TRK RCVR #4______ TRK RCVR #4______ #2 GMT______ #4 GMT______ TRK RCVR #2______ TRK RCVR #2______ TRK RCVR #4______ TRK RCVR #4______

AIRCRAFT # 372 | DATA RUN #6 | DATE
FLIGHT # 15 | VHF ACQ OPERATOR J-3
FLIGHT CARD #

ITEM	DIRECTED BY	PERFORMED BY	TEST	FUNCTION
				#5 GMT______ #6 GMT______ TRK RCVR #2______ TRK RCVR #2______ TRK RCVR #4______ TRK RCVR #4______
	MCC	Record		Measure S/N level on MCC MARK of USB baseband signal from SDD 1 and 2. Record· #1 GMT______ #4 GMT______ SDD 1 ______ SDD 1 ______ SDD 2 ______ SDD 2 ______ #2 GMT______ #5 GMT______ SDD 1 ______ SDD 1 ______ SDD 2 ______ SDD 2 ______ #3 GMT______ #6 GMT______ SDD 1 ______ SDD 1 ______ SDD 2 ______ SDD 2 ______
	MCC	TLM		Measure C/N level on MCC MARK of 10 MC unlimited output of VHF TLM RCVR #4 both channels. Record #1 GMT______ #4 GMT______ CH 1 ______ CH 1 ______ CH 2 ______ CH 2 ______ #2 GMT______ #5 GMT______ CH 1 ______ CH 1 ______ CH 2 ______ CH 2 ______ #3 GMT______ #6 GMT______ CH 1 ______ CH 1______ CH 2 ______ CH 2______

AIRCRAFT # 372 DATA RUN #6 DATE: ____________

FLIGHT # 15

FLIGHT CARD # ____________ VHF ACQ ________ OPERATOR J

ITEM	DIRECTED BY	PERFORMED BY	TEST	FUNCTION
14		All		Continue tracking functions.
15		FTE		Notify ground station and MCC at Point 5 on flight pattern (start of outbound turn).
		Navigator		Record Point 5 GMT________________.
		Ground Station		Remove modulation from USB and VHF carriers. Prepare for Rate Memory test.
16	MCC	Record		Measure noise level USB baseband SDD #1 and 2. Record GMT____________ SDD #1____________ SDD# 2____________
	MCC	Record		Stop WB recorder.
17		MCC		When A/RIA is approximately 20° into the turn, direct Ground Station to remove UHF signal for six seconds on MARK. GMT____________
	MCC	Ground Station		Remove UHF signal for six seconds.
		Antenna		Note RATE MEMORY lamp for six seconds. Record GMT of AUTO TRACK continuation. GMT____________
18		MCC		Direct Ground Station to remove UHF signal for nine seconds on MARK. GMT____________
		Ground Station		Remove UHF signal for nine seconds.
		Antenna		Note RATE MEMORY lamp for nine seconds. Record GMT of AUTO TRACK continuation. GMT____________

AIRCRAFT # 372
FLIGHT # 15
FLIGHT CARD #

DATA RUN #6
VHF ACQ OPERATOR J-S

DATE:

ITEM	DIRECTED BY	PERFORMED BY	TEST	FUNCTION
19	MCC-	Antenna		Continue to track to L.O.S. or near limit. Record: Antenna AZ position ______° Antenna E position ______° Aircraft Heading ______° GMT ______
20		Pilot		Notify MCC at Point 6 on Flight Pattern (90° to data heading outbound).
21	MCC	Antenna		Stow antenna.
		HF		Inform HF ground station that track has been broken.

PRE-FLIGHT SPECIAL TESTS (SAMPLE)

1. Acquire and Track at UHF, with 51.2 KBPS data, at a signal power of -90 dBm at the directional coupler: (2287.5 MHz)

   a. Measure Carrier-Noise of unfiltered 10 MHz output of Trk Rcvrs #2 and #4.

      Trk Rcvr #2: Noise Only __________ C+N (51.2 KBPS MOD) __________

      Trk Rcvr #4: Noise Only __________ C+N (51.2 KBPS MOD) __________

   b. Measure Signal-Noise at the WB recorder input of PCM outputs of SDD #1 and #2:

      SDD #1 Carrier Only __________ C+51.2 KBPS MOD __________

      SDD #2 Carrier Only __________ C+51.2 KBPS MOD __________

2. Insert a 1000 Hz tone, at 296.8 MHz, into the directional coupler at a power of -113 dBm (measured at the coupler):

   a. Measure S/N at HF Patch of Output of Voice

      SDD #1 Carrier Only __________ C+1000 Hz tone __________

      SDD #2 Carrier Only __________ C+1000 Hz tone __________

3. Acquire and Track at UHF, with 51.2 KBPS data, at a signal power of -105 dBm at the directional coupler: (2287.5 MHz)

   a. Measure Carrier-Noise of unfiltered 10 MHz output of Trk Rcvr #2 and #4.

      Trk Rcvr #2: Noise Only __________ C+N (51.2 KBPS Mod) __________

      Trk Rcvr #4: Noise Only __________ C+N (51.2 KBPS Mod) __________

   b. Measure Signal-Noise at WB recorder input of PCM outputs of SDD #1 and #2.

      SDD #1 Carrier Only __________ C+51.2 KBPS Mod __________

      SDD #2 Carrier Only __________ C+51.2 KBPS Mod __________

4. Acquire and Track at VHF, with 51.2 KBPS data, at a signal power of -107 dBm at the directional coupler.

a. Measure Carrier-Noise of Unfiltered 10 MHz Output of TLM Rcvr #4:

Channel 1: Noise Only ________ C+51.2 KBPS Mod ________

Channel 2: Noise Only ________ C+51.2 KBPS Mod ________

b. Measure Signal-Noise at WB recorder Input of PCM Output of TLM RCVR #4:

Channel 1: Carrier Only ________ C+51.2 KBPS Mod ________

Channel 2: Carrier Only ________ C+51.2 KBPS Mod ________

5. Acquire and Track At UHF, with 1.6 KBPS data, at a signal power of -115.6 at the directional coupler: (2287.5 MHz)

a. Measure Carrier-Noise of unfiltered 10 MHz output of Trk Rcvr #2 and #4.

Trk Rcvr #2: Noise Only ________ C+1.6 KBPS data ________

Trk Rcvr #4: Noise Only ________ C+1.6 KBPS data ________

b. Measure Signal-Noise at the WB recorder input of PCM outputs of SDD #1 and #2.

SDD #1 Carrier Only ________ C+1.6 KBPS data ________

SDD #2 Carrier Only ________ C+1.6 KBPS data ________

c. Measure Signal-Noise of USB voice with 1000 Hz tone on voice subcarrier at IF patch (voice combiner output):

Voice Combiner: Subcarrier + Carrier Only ________ SC+C+1000 Hz tone

6. Acquire and Track at VHF, with 51.2 KBPS data, at a signal power of -92 dBm at the directional coupler.

a. Measure Carrier-Noise of unfiltered 10 MHz output of TLM Rcvr #4:

Channel 1: Noise Only ________ C+51.2 KBPS Mod ________

Channel 2: Noise Only ________ C+51.2 KBPS Mod ________

b. Measure Signal-Noise at WB output of PCM output of TLM RCVR #4:

Channel 1: Carrier Only ________ C+51.2 KBPS Mod ________

Channel 2: Carrier Only ________ C+51.2 KBPS Mod ________

A/RIA Technical Note No. A0138

UHF A/RIA RECEIVER FREQUENCY ACQUISITION

Originator: M. Taylor

March 18, 1966

1. PURPOSE

The purpose of this technical note is to re-evaluate the UHF down-link receiver frequency acquisition problem.

2. RESULTS OF ANALYSIS

The analysis is based on Doppler shift values and rate of change of Doppler shift values for the Apollo injection mission since it was shown in the PDP that these values exceed those of any other mission. The maximum down-link Doppler shift is ±85 kc/s when the spacecraft reaches escape velocity (after injection burn). The maximum down-link rate of change of Doppler shift is -1.2 kc/sec^2 (super 2).

The higher Doppler shift value (±85 kc/s) was used in the analysis to determine worst case conditions.

The details of the analysis for the mission phases of interest are shown in Figures II-1 through II-6. Receiver frequency search requirements are summarized in Table 1-1.

It is seen that the greatest required excursion for the receiver frequency search sweep is ±76.5 kc/s and that it must be possible to offset the center of this sweep over a range of ±85 kc/s from the nominal receiver frequency. Of the various selectable receiver phase-lock loop bandwidths provided, only the highest value of 1000 Hz (one-sided) is useable. Selection of this bandwidth provides an automatic search zone of 370 kc/s ±20 (296 to 444 kc/s) with a search rate of 300 kc/sec^2. Since the minimum value of 296 kc/s for the total excursion of this sweep is 1.93 times the required 153 kc/s excursion, ample search range margin is provided.

The 300 Hz and 100 Hz (one-sided) phase-lock loop bandwidths cannot be used for acquisition since they provide total sweep excursions of only 75 kc/s ±40 and 25 kc/s ±40, respectively. The minimum excursion value calculated for any case analyzed is 90 kc/s.

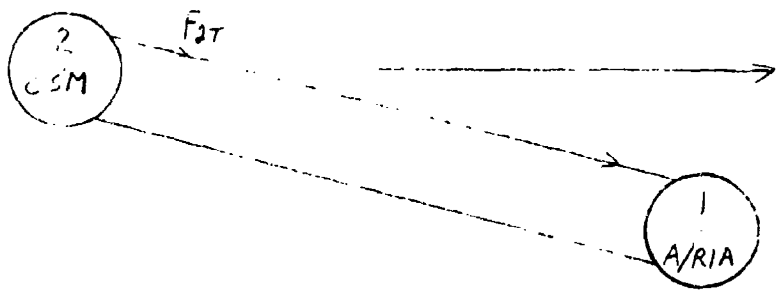
While the sweep excursion for the 1000 Hz phase-lock loop bandwidth is more than adequate, the time required for one sweep is more than assumed in the PDP acquisition analysis. The sector scan pattern analysis contained in A/RIA Technical Note No. 0118, for example, assumed a frequency acquisition time of 0.1 second. The search rate specified for the 1000 Hz phase-lock loop bandwidth is 300 kc/sec^2. This required a sweep period of 1.23 seconds for the nominal 370 kc/s excursion value. A recalculation of the sector scan times contained in Table 1 of Technical Note No. 0118 must be made using this longer frequency acquisition time. The results of these recalculations will be present in a subsequent technical note.

TABLE 1. SUMMARY OF RECEIVER FREQUENCY SEARCH REQUIREMENTS

Figure	Case	Mission Phase	Frequency Offset at Center of Sweep	Required Excursion About Offset	Sweep Excursion Limits	Useable Receiver Phase-Lock Loop Band-width (one-sided)	Minimum Receiver Excursion About Offset
1	1A	Initial Acquisition on incoming leg of Apollo injection mission before CSM receiver locks on A/RIA transmitter.	+85 kc/s	±58 kc/s	+27 to +143 kc/s	1000 cps	±148 kc/s
2	1B	Reacquisition on incoming leg of Apollo injection mission after CSM receiver locks on A/RIA transmitter	+85 kc/s	±76.5 kc/s	+8.5 to +161.5 kc/s	1000 cps	±148 kc/s
3	2A	Initial acquisition on outgoing leg of Apollo injection mission before CSM receiver locks on A/RIA transmitter	-85 kc/s	±[illegible] kc/s	-27 to -143 kc/s	1000 cps	±148 kc/s
4	2B	Reacquisition on outgoing leg of Apollo injection mission after CSM receiver locks on A/RIA transmitter	-85 kc/s	±76.5 kc/s	-8.5 to -161.5 kc/s	1000 cps	±148 kc/s
5	3A	Handover: Acquisition by Aircraft B receiver when CSM receiver is initially locked to Aircraft A transmitter	+85 kc/s	±45.1 kc/s	+39.9 to +130.1 kc/s	1000 cps	±1[illegible]
6	3B	Handover: Possible reacquisition by Aircraft B receiver when Aircraft A transmitter is turned off	+85 kc/s	±45.1 kc/s	+39.9 to +130.1 kc/s	1000 cps	±148 kc/s

FIGURE 1

Case 1A. Initial acquisition on incoming leg of Apollo injection mission before CSM receiver locks on A/RIA transmitter



F_{2TO}	=	Nominal frequency of CSM Transmitter = 2287.5 mc/s
F_{2T}	=	Actual frequency of CSM transmitter
ΔF_{2T}	=	Transmitter frequency drift (magnitude) = 34.5 kc/s (0.0015%, Reference 1)
F_{DD}	=	Estimated down-link Doppler shift = +85 kc/s
ΔF_{DD}	=	Uncertainty in estimating Doppler shift = 21.2 kc/s (25%)
F_{R1O}	=	Nominal frequency of A/RIA receiver = 2287.5 mc/s
ΔF_{R1}	=	Receiver frequency offset at center of sweep
F_o	=	Required amplitude of sweep (½ total excursion)
F_s	=	Receiver frequency setting tolerance = 2.3 kc/s (1 part in 10^6)
ΔF_{R1}	=	F_{DD} = +85 kc/s
F_o	=	$\Delta F_{2T} + \Delta F_{DD} + F_S$ = 34.5 + 21.2 + 2.3 = 58 kc/s
$2F_o$	=	116 kc/s (total excursion)

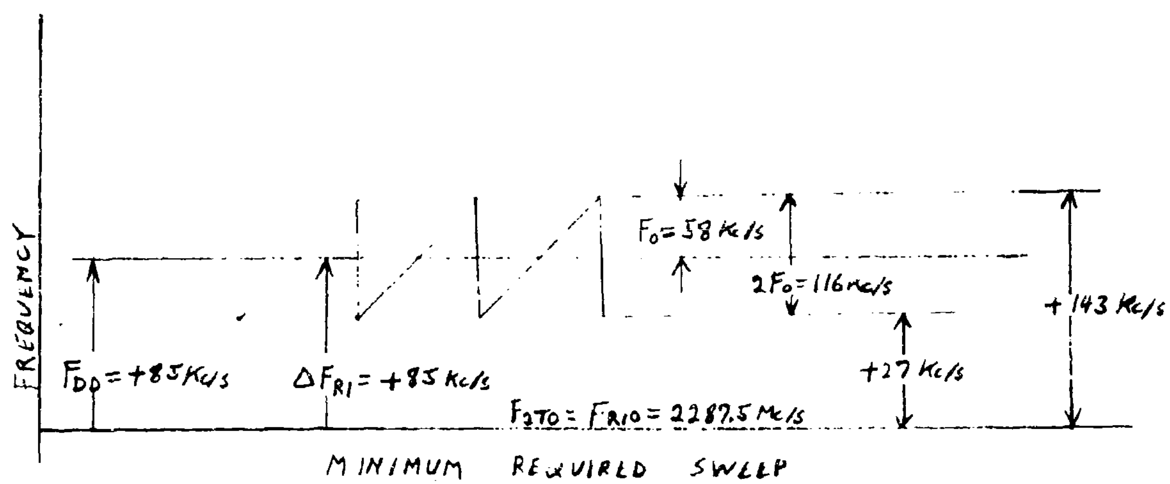


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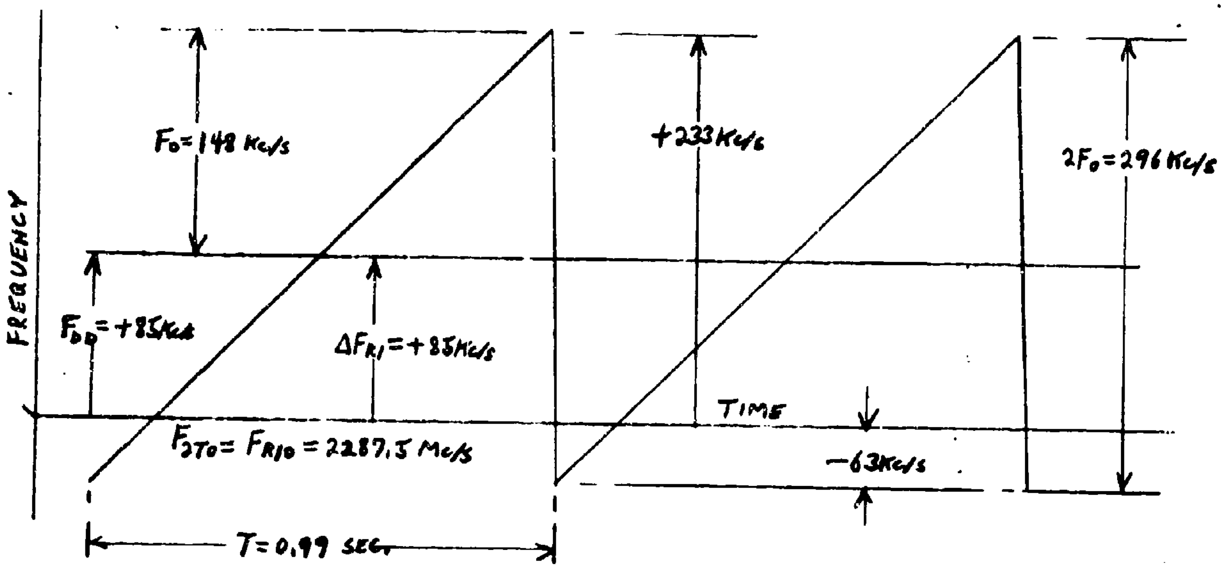
FIGURE 1 (continued)

The 300 cps phase-lock loop bandwidth ($2B_{LO}$ = 600 cps) position has a total sweep excursion of 75 kc/s ±40% (45 kc/s to 105 kc/s). This is inadequate.

The 1000 cps phase-lock loop bandwidth ($2\ B_{LO}$ = 2000 cps) position must be used. This has a total sweep excursion of 370 kc/s ±20% (296 kc/s to 444 kc/s) which exceeds the 116 kc/s requirement.



MINIMUM ACTUAL SWEEP

PAGE 5

FIGURE 2

Case 1B. Reacquisition on incoming leg of Apollo injection mission after CSM receiver locks on A/RIA transmitter

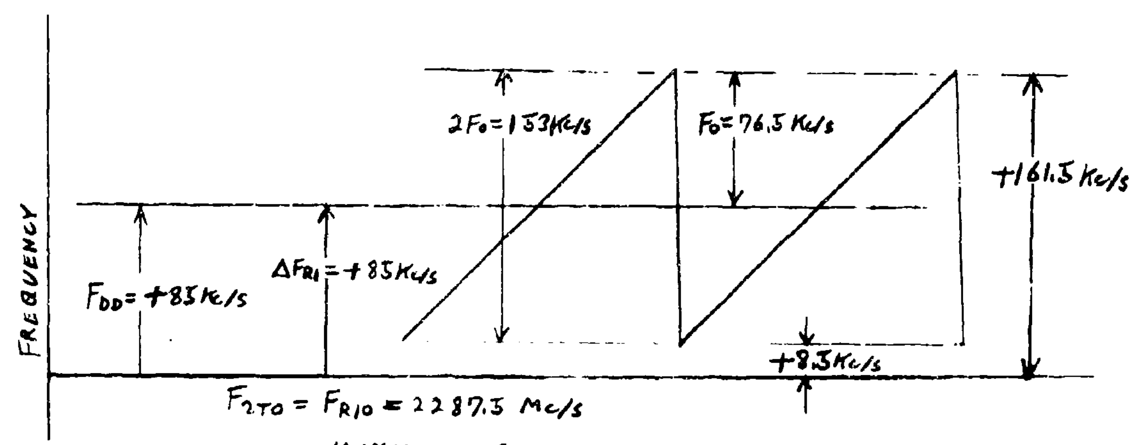
When the CSM receiver locks on the A/RIA transmitter, the CSM transmitter source shifts from the auxiliary oscillator to the VCO. The VCO may be pulled off nominal frequency by as much as ±53 kc/s per Technical Note A0136. Thus

ΔF_{2T} = 53 kc/s

$F_o = \Delta F_{2T} + F_{DD} + F_S = 53 + 21.2 + 2.3 = 76.5$ kc/s

$2F_o$ = 153 kc/s

$\Delta F_{R1} = F_{DD} = +85$ kc/s

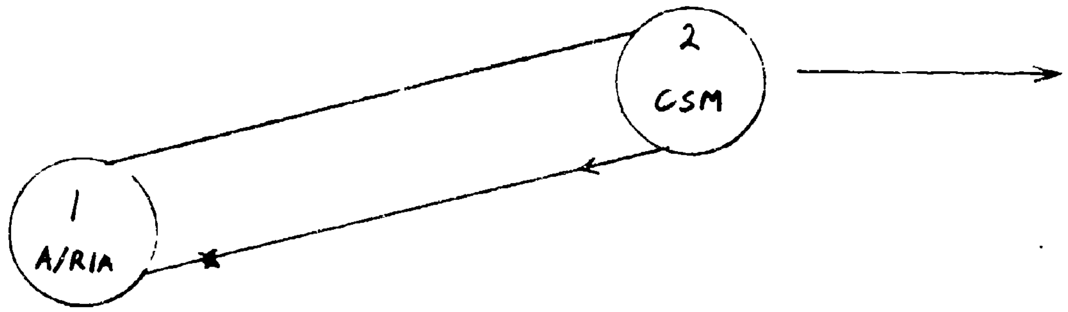


MINIMUM REQUIRED SWEEP

Use of 1000 cps phase-lock loop bandwidth ($2B_{LO}$ = 2000 cps) position will provide a greater sweep range than required above.

FIGURE 3

Case 2A. Initial acquisition on outgoing leg of Apollo injection mission before CSM receiver locks on A/RIA transmitter



ΔF_{2T} = Transmitter frequency drift (magnitude) = 34.5 kc/s (0.0015%, Reference 1)

F_{DD} = Estimated down-link Doppler shift = -85 kc/s

ΔF_{DD} = Uncertainty in estimating Doppler shift = 21.2 kc/s (25%)

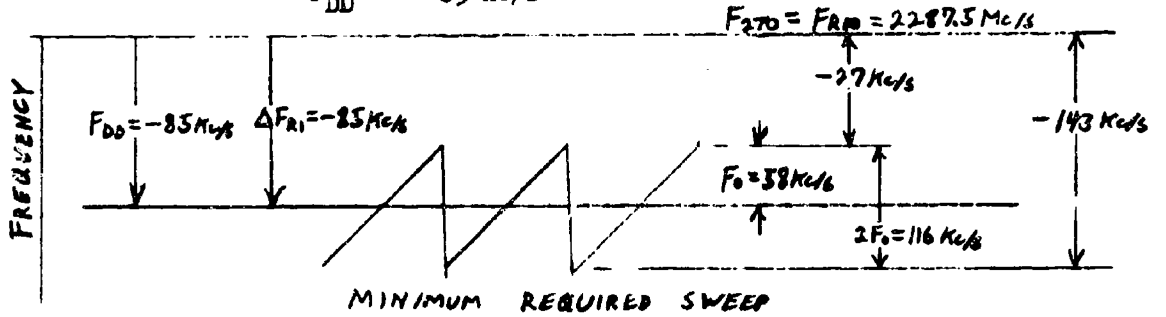
F_S = Receiver frequency setting tolerance = 2.3 kc/s (1 part in 10^6)

F_o = Required amplitude of sweep (1/2 total excursion)

$= \Delta F_{2T} + \Delta F_{DD} + F_S = 34.5 + 21.2 + 2.3 = 58$ kc/s

ΔF_{R1} = Receiver frequency offset at center of sweep

$= F_{DD} = -85$ kc/s



Use of 1000 cps phase-lock loop bandwidth (2 B_{LO} = 2000 cps) position will provide a greater sweep range than required above.

FIGURE 4

Case 2B. Reacquisition on outgoing leg of Apollo injection mission after CSM receiver locks on A/RIA transmitter

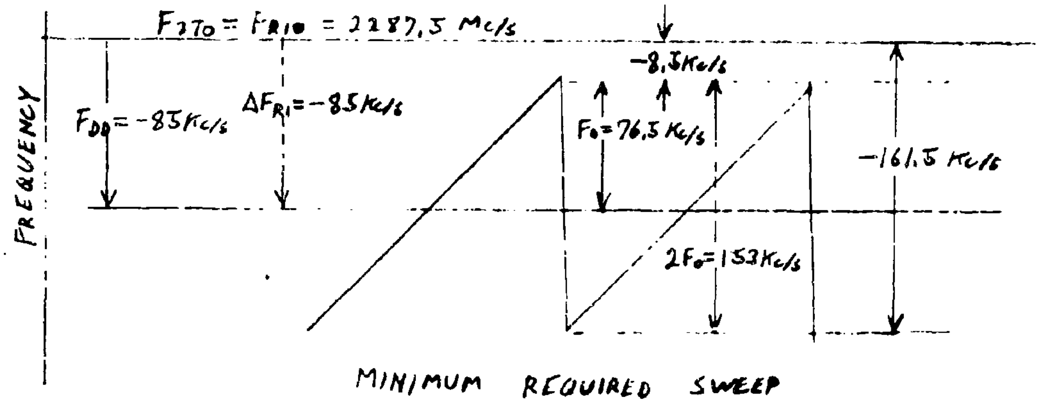
When the CSM receiver locks on the A/RIA transmitter, the CSM transmitter source shifts from the auxiliary oscillator to the VCO. The VCO may be pulled off nominal frequency by as much as ±53 kc/s per Technical Note A0136. Thus

$\Delta F_{2T} = 53$ kc/s

$F_o = \Delta F_{2T} + \Delta F_{DD} + F_S = 53 + 21.2 + 2.3 = 76.5$ kc/s

$2F_o = 153$ kc/s

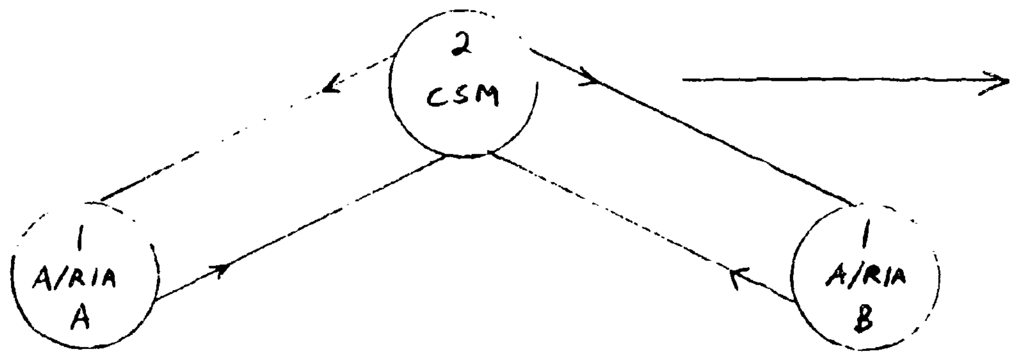
$\Delta F_{R1} = F_{DD} = -35$ kc/s



Use of 1000 cps phase-lock loop bandwidth ($2 B_{LO}$ = 2000 cps) position will provide a greater sweep range than required above.

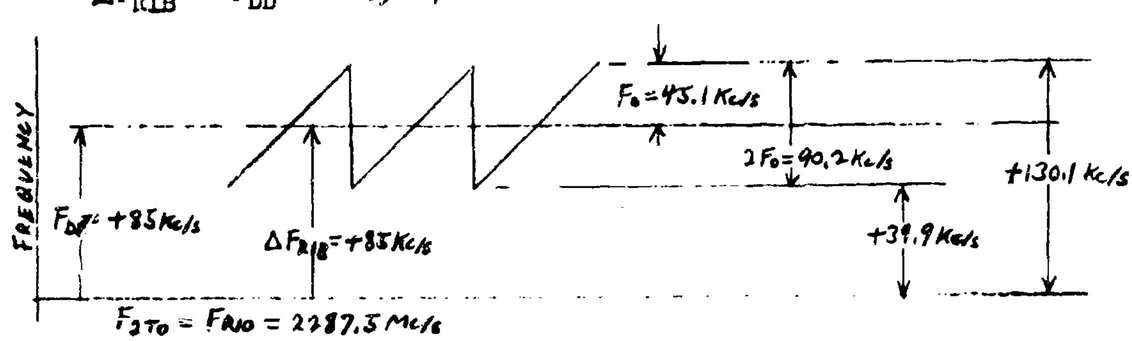
FIGURE 5

Case 3A. Handover: Acquisition by Aircraft B receiver when CSM receiver is initially locked to Aircraft A transmitter



The CSM VCO may be pulled off nominal frequency by as much as ± 21.6 kc/s by the Aircraft A transmitter per Technical Note A0136. Thus

$$\Delta F_{2T} = 21.6 \text{ kc/s}$$
$$\Delta F_{DD} = 21.2 \text{ kc/s}$$
$$F_s = 2.3 \text{ kc/s}$$
$$F_c = \Delta F_{2T} + \Delta F_{DD} + F_s = 21.6 + 21.2 + 2.3 = 45.1 \text{ kc/s}$$
$$2F_c = 90.2 \text{ kc/s}$$
$$\Delta F_{R1B} = F_{DD} = +85 \text{ kd/s}$$



MINIMUM REQUIRED SWEEP

Use of 1000 cps phase-lock loop bandwidth ($2B_{LO} = 2000$ cps) position will provide a greater sweep range than required above.

FIGURE 6

Case 3B. Handover: Possible reacquisition by Aircraft B receiver when Aircraft A transmitter is turned off

Since the Aircraft B transmitter is tuned to zero beat with the Aircraft A transmitter before the Aircraft A transmitter is turned off, the jump in the CSM VCO when the A transmitter is turned off should not be great enough to cause the A/RIA receiver to lose lock. If lock is lost, the search requirements will be essentially the same as for case 3A.

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Reference 1: North American Aviation, Inc. Specification MC 473-0026 on Unified S-Band Equipment as amended by Procurement Document Changes PDC-1, 2, and 3.

A/RIA Technical Note A0141

REVISED CALCULATION OF MARGINS FOR CSM UNIFIED S-BAND DOWN-LINK CHANNEL

Originators: G. Soukup
M. Taylor

May 20, 1966

APPENDIX B

Aircraft Spacing

The optimum spacing between the two aircraft A and B required to cover the Apollo injection mission data recording interval may be determined from study of the graphs of Figure 1. In this figure, the curve denoted Aircraft A is a plot of slant range versus mission time, referenced to the start of the data interval for the aircraft which will first acquire the spacecraft. The geometrical configuration is the same as that assumed in Technical Note No. 0009 for this mission. These parameters are:

Aircraft altitude:	35,000 feet (5.75 N.M.)
Spacecraft altitude:	Varying from 100 N.M. prior to injection burn to 200 N.M. at the end of the data interval
Aircraft offset:	240 N.M. from track at a point 720 N.M. down range from the spacecraft at time = 0

The spacecraft should be within line-of-sight range of aircraft A (1190 N.M.) at a time of 105 seconds prior to the start of the data interval. The period of 105 seconds is available for acquisition by the A/RIA antenna tracking system and for sweeping the A/RIA transmitter until lock-up of the spacecraft receiver is achieved.

This time allowance is based on the following steps in the procedure:

Delay in starting antenna acquisition scan	5 seconds
Time for 1 antenna acquisition scan	20 seconds
Time to repeat acquisition scan if first scan is unsuccessful	20 seconds
Time to determine valid tracking and start transmitter frequency search	10 seconds
Time for one transmitter frequency search sweep cycle	25 seconds
Time to repeat transmitter frequency search cycle	25 seconds
Total	105 seconds

By the time the data interval begins, the range between the spacecraft and aircraft A has decreased to 760 N.M.

Range versus time curves are also shown in Figure 1 for a second aircraft B positioned down range from aircraft A by the distances indicated, i.e., 800, 1000, 1200, 1400, 1600, 1800, and 2000 N.M. The same offset of 240 N.M. from the track is assumed for aircraft B. The maximum line-of-sight range is a function of spacecraft altitude and varies with mission time as indicated by the dashed curve in Figure 1. Since the spacecraft altitude is assumed

constant at 100 N.M. until time t = +60 seconds, the line-of-sight range remains constant until this time. During the injection burn period the spacecraft altitude is increasing, causing the steady increase in line-of-sight range as indicated.

The selection of an optimum spacing of aircraft B from aircraft A is made to satisfy the following criteria:

1. Provide an overlap period of sufficient duration for the procedure involved in handover from Aircraft A to Aircraft B. (Assume 60 seconds minimum).

2. Locate the handover region as to correlate with the nearly constant slope increasing range portion of the curve for aircraft A and the constant slope decreasing range portion of the curve for aircraft B. This is necessary to stabilize the Doppler frequency shifter for both aircraft at values which can be estimated quite accurately. (See A/RIA Technical Notes A0136 and A0138).

3. Minimize the maximum range value for which either aircraft A or B must receive voice and data transmissions during the 10 minute data interval.

An examination of the curves of Figure 1 shows that the three criteria above are best met by selection of a down range spacing of aircraft B from aircraft A of 1600 N.M. Using this spacing results in the following operational parameters:

Maximum range for aircraft A to start acquisition procedure: 1190 N.M. Time available for aircraft A acquisition prior to data interval: 105 seconds.
Maximum range for aircraft A to start data reception: 760 N.M.
Range for aircraft A at start of handover period: 500 N.M.
Maximum range for aircraft A to receive data at end of handover period: 835 N.M.
Range for aircraft B to start acquisition: 1200 N.M.
Maximum range for aircraft B to start data reception (at end of handover period): 835 N.M.
Time available for handover procedure: 70 seconds
Maximum range for aircraft B to receive data at end of data interval: 890 N.M.

It is seen that for proper spacing of the two aircraft, continuous data reception during the 10 minute data interval is provided and the maximum range for which either aircraft must receive data will not exceed 900 N.M. Thus, while a maximum range of approximately 1200 N.M. must be assumed in calculating system

APPENDIX B (continued)

acquisition performance, it is reasonable to reduce the maximum range to 900 N.M. for calculation of voice and data reception performance. The increase in signal strength provided by this reduction in range is

$$20 \log \frac{1200}{900} = 2.5 \text{ db}$$

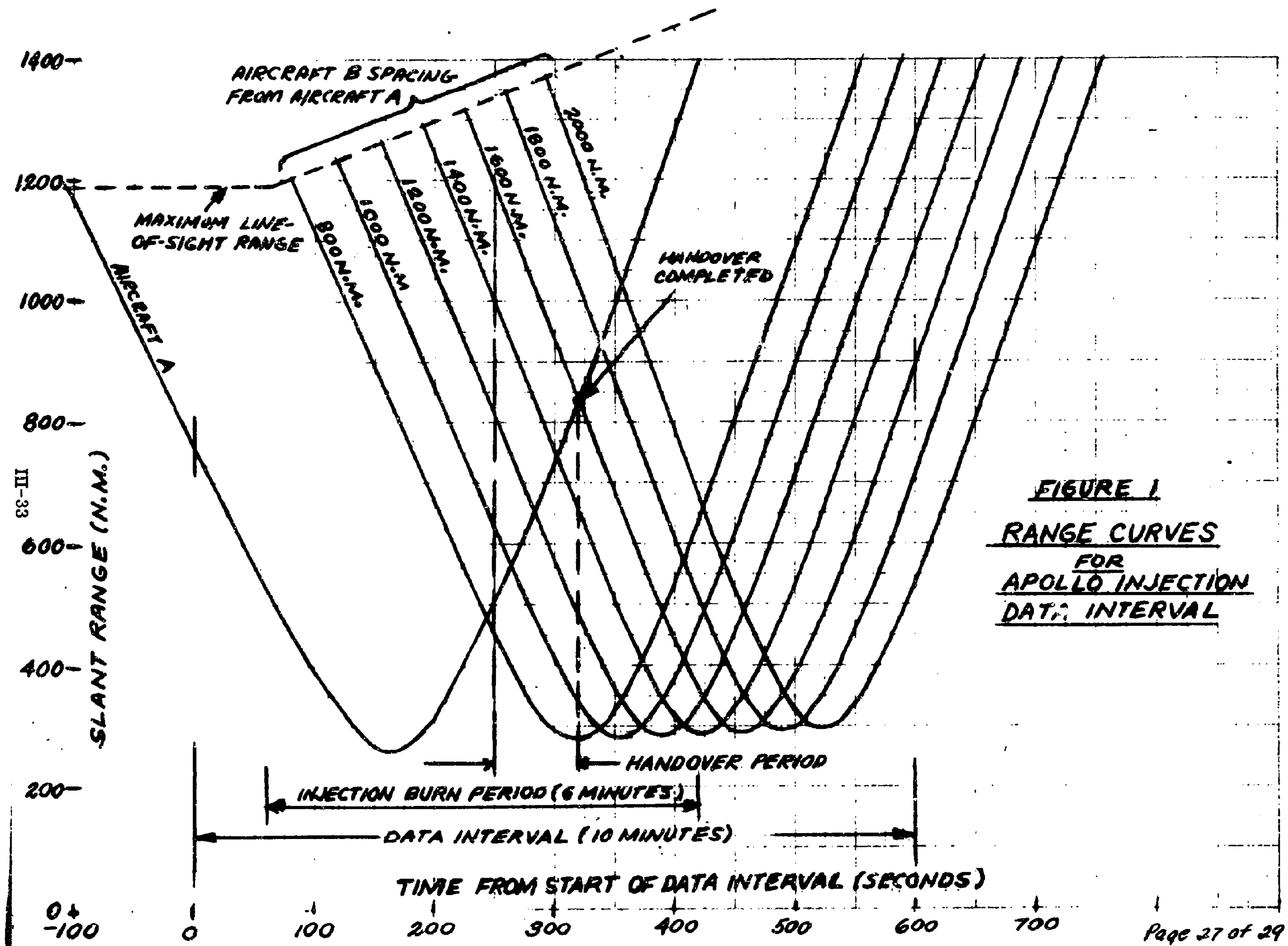
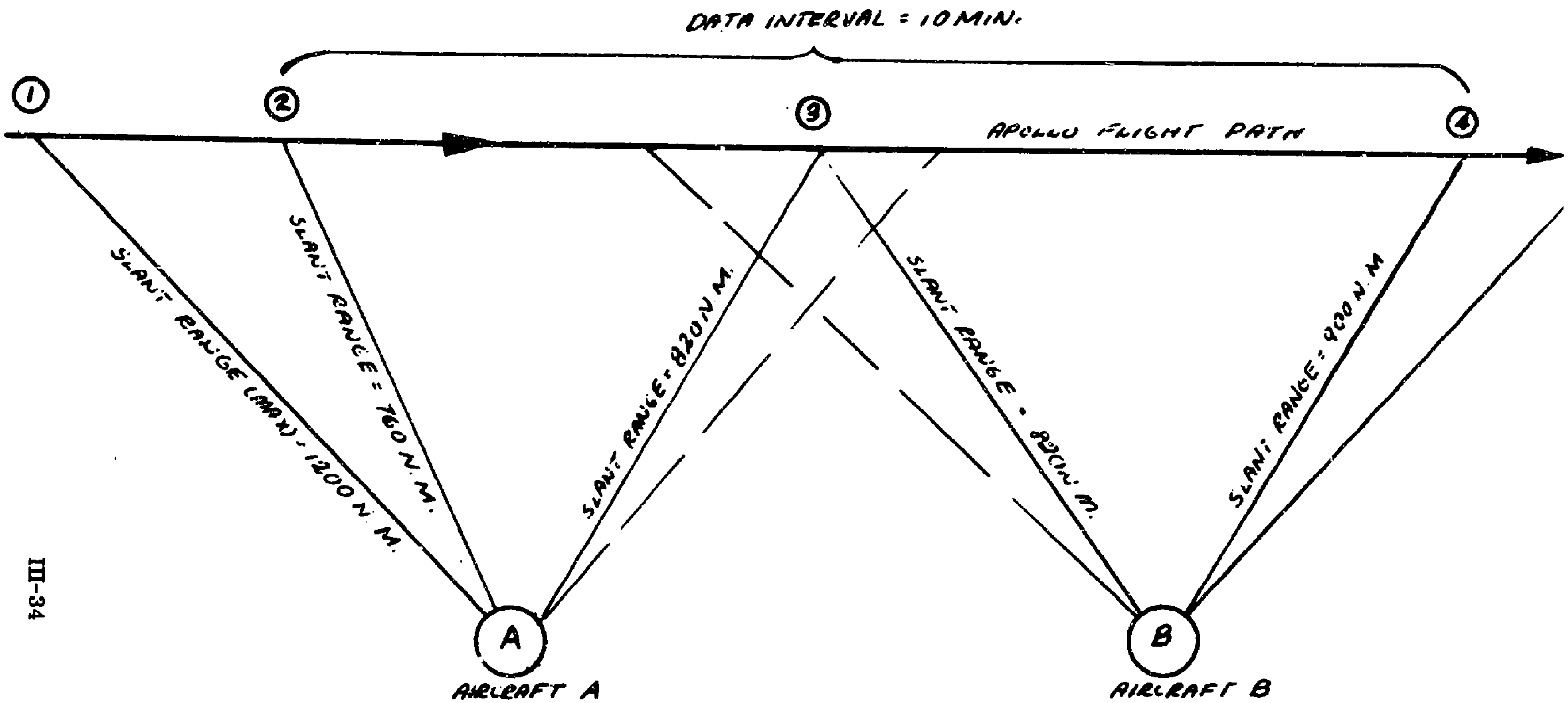


FIGURE 1
RANGE CURVES
FOR
APOLLO INJECTION
DATA INTERVAL



SEQUENCE OF EVENTS

AIRCRAFT Ⓐ INITIATES ANTENNA SCAN FOR ACQUISITION AND TRACK AT ①

FROM ① TO ②, ACQUISITION AND LOCK ON COMPLETE

FROM ② TO ③, START DATA INTERVAL WITH AIRCRAFT Ⓐ IN CONTROL

AT ③, ACHIEVE "HANDOVER" – FROM AIRCRAFT Ⓐ TO AIRCRAFT Ⓑ

FROM ③ TO ④, COMPLETE DATA INTERVAL WITH AIRCRAFT Ⓑ IN CONTROL.

FIGURE 2

Amendment B
A/RIA Technical No. A0143

CALCULATION OF SIGNAL STRENGTH LEVELS
FOR A/RIA SYSTEM SPECIFICATIONS

Originator: M. Taylor
August 29, 1966

1. Introduction.

The purpose of this amendment to A/RIA Technical Note No. A0143 is to up-date the calculation of signal strength levels to agree with the changes incorporated in Amendment B of A/RIA Technical Note No. A0141.

2. Summary.

The detailed calculations of signal level are given in Appendix A. The values of the various S-band parameters used in Appendix A are in agreement with those of Amendment B of Technical Note No. A0141. The values of the VHF parameters are in agreement with those of Technical Note No. A0143 except that polarization loss and radome loss values have been revised and the maximum range for telemetry has been changed to 900 N. M.

The results of the margin calculations in Amendment B of Technical Note No. A0141 are used to adjust the S-band signal levels as noted on the sheets of Appendix A to reference values equivalent to 0 db margin. In the ease of VHF the signal levels are changed from the values given in the original issue of Technical Note No. A0143 only to the extent of the changes in values of polarization loss, radome loss and maximum range noted above.

TABLE I

SIGNAL LEVELS FOR A/RIA SYSTEM SPECIFICATIONS

Frequency Band	Mode of Operation	Bit Rate	Power Density DBW/M^2	Power Density Watts/M^2	Capture Area	Sum Channel Carrier Level at Antenna (DBM)	Sum Channel Carrier Level at Directional Coupler Output (DBM)
Unified S-band (2287.5 mc/s)	Acquisition & Tracking	1.6 KBPS or 51.2 KBPS	-153.8	4.2×10^{-16}	+ 2.6	-121.2	-123.3
Unified S-band (2287.5 mc/s)	Voice/Data	1.6 KBPS	-145.2	3.0×10^{-15}	+ 2.6	-112.6	-114.6
		51.2 KBPS	-136.1	2.4×10^{-14}	+ 2.6	-103.5	-105.5
VHF AM Voice (296.8 mc/s)	Voice	---	-142.7	5.4×10^{-15}	+ 2.1	-110.6	-112.3
VHF PCM/FM (237.8 mc/s)	Data	1.6 KBPS or 51.2 KBPS	-139.6	1.1×10^{-14}	+ 4.1	-105.5	-107.2

Appendix A

CALCULATION OF POWER DENSITY

Power density is given by

$$p_0 = \frac{p_t}{4\pi R^2}\left(\frac{g_t}{l}\right)$$

where pt = transmitter power in watts
R = distance in meters
g_t = transmitting antenna power gain ratio
l = total loss ratio for losses from transmitter to receiving antenna with the exception of space attention

Using captial letters for decibel notation

$$P_o = P_t + G_t - L - 10 \log (4\pi R^2)$$

where P_t = transmitter power in DBW
G_t = transmitting antenna gain in DB
L = total loss in DB
P_o = power density in DBW/m^2

The signal power at the antenna terminals is given by

$$p_r = p_o \text{ (capture ratio)}$$
$$p_o \left(\frac{G_A \lambda^2}{4\pi}\right)$$

In decibel form

$$P_r = P_o + \left(\frac{G_A\lambda^2}{4\pi}\right)_{DB} = P_o + 10 \log \left(\frac{G_A\lambda^2}{4\pi}\right)$$

Values of the capture factor are tabulated below:

Frequency (Mc/s)	Antenna Gain (DB)	Antenna Gain Power Ratio G_r	λ (m)	$\frac{G_A\lambda^2}{4\pi}$ (m^2)	$10 \log \left(\frac{G_A\lambda^2}{4\pi}\right)$
VHF AM Voice (296.8 mc/s)	+13.0	20.0	1.01	1.625	+ 2.1
VHF PCM/FM (237.8 mc/s)	+13.0	20.0	1.26	2.54	+ 4.1
Unified S-Band (2287.5 mc/s)	+31.3	1346	0.131	1.842	+ 2.6

APOLLO UNIFIED S-BAND (2287.5 mc/s) ACQUISITION & TRACKING

Block I or Block II, either 1.6 or 51.2 KBPS bit rate (reference Table I, Amendment B, Technical Note No. A0141).

P_t	(Transmitter power, 14.4W)	+11.6 DBW
G_t	(Transmitting Antenna gain)	- 3.0 DB
$-L$	$-L_t$ (Transmitting circuit loss)	- 5.6 DB
	$-L_a$ (Atmospheric loss)	- 2.0 DB
	$-L_p$ (Polarization loss)	- 4.1 DB
	$-L_r$ (Radome loss)	- 0.7 DB
	$-10 \log (4\pi R^2)$ ($R = 2.22 \times 10^6$m for 1200 N.M.)	- 137.9 DB
$P_o =$		-141.7 DBW/m^2

Correction to reduce margin to 0 db in Table I, Amendment B of Technical Note No. A0141 — -12.1 DB

Corrected power density — -153.8 DBM/m^2 or 4.16×10^{-16} watts/m^2

$$P_r = P_o + 10 \log\left(\frac{G_A \lambda^2}{4\pi}\right) = -153.8 + 2.6 = -151.2 \text{ DBW or } -121.2 \text{ DBM}$$

APOLLO UNIFIED S-BAND (2287.5 mc/s) VOICE/DATA

(reference Table II, Amendment B, Technical Note No. A0141)

		51.2 KBPS	1.6 KBPS
P_t	(Transmitter power 14.4W)	+11.6 DBW	+11.6 DBW
G_t	(Transmitting Antenna gain)	- 3.0 DB	- 3.0 DB
$-L$	L_t (Transmitting circuit loss)	- 5.6 DB	- 5.6 DB
	L_a (Atmospheric loss)	- 2.0 DB	- 2.0 DB
	L_p (Polarization loss)	- 4.1 DB	- 0.5 DB
	L_r (Radome loss)	- 0.7 DB	- 0.7 DB
$-10 \log (4\pi R^2)$	($R=1.67 \times 10^6$m for 900 N.M.)	-135.4 DB	-135.4 DB

	51.2 KBPS	1.6 KBPS
$P_o =$	-139.2 DBW/m^2	-135.6 DBW/m^2
Correction to change margin to 10db in Table II, Amendment B of Technical Note No. A0141	+ 3.1 DB	- 9.6 DB
Corrected power density	-136.1 DBW/m^2 or 2.45×10^{-14} watts/m^2	-145.2 DBW/m^2 or 3.02×10^{-15} watts/m^2
$P_r = P_o + 10 \log\left(\frac{G_A \lambda^2}{4\pi}\right)$ $= P_o + 2.6 =$	-133.5 DBW or -103.5 DBM	-142.6 DBW or -112.6 DBM

VHF AM VOICE DOWN-LINK (296.8 mc/s at 1200 N. M.)

P_t	(Transmitter power, 5W)	+ 7.0 DBW
G_t	(Transmitting antenna gain)	- 3.0 DB
$-L$	$-L_t$ (Transmitting circuit loss)	-3.0 DB
	$-L_a$ (Atmospheric loss)	-1.0 DB
	$-L_p$ (Polarization loss)	-4.1 DB *
	$-L_r$ (Radome loss)	-0.7 DB **
	$-10 \log (4\pi R^2)$ ($R = 2.22 \times 10^6$m for 1200 N. M.)	-137.9 DB

$P_o =$ -142.7 DBW/m^2 or 5.37×10^{-15} $watts/m^2$

$$P_r = P_o + 10 \log\left(\frac{G_r \lambda^2}{4\pi}\right) = -142.7 + 2.1 = -140.6 \text{ DBW or } -110.6 \text{ DBM}$$

* Based on linear spacecraft polarization and circular aircraft polarization of 2 db ellipticity with worst case orientation. See Note 7 of Amendment A to Technical Note No. A0141.

** Based on paragraph 3.1.1.1.1.2.1 of Specification CP 100009A.

VHF FM TM (237.8 mc/s at 900 N. M.)

P_t	(Transmitter power, 10 W)	+10.0 DBW
G_t	(Transmitting Antenna gain)	− 3.0 DB
$-L$	$-L_t$ (Transmitting circuit loss)	− 5.4 DB
	$-L_a$ (Atmospheric loss)	− 1.0 DB
	$-L_p$ (Polarization loss)	− 4.1 DB *
	$-L_r$ (Radome loss)	− 0.7 DB **
	−) log ($4\pi R^2$) (R=1.667 x 10^6m for 900 N. M.)	−135.4 db

P_o = −139.6 DBW/m^2 or 1.09×10^{-14} watts/m^2

$$P_r = P_o + 10 \log\left(\frac{G_r \lambda^2}{4\pi}\right) = -139.6 + 4.1 = -135.5 \text{ DBW or } -105.5 \text{ DBM}$$

* Based on linear spacecraft polarization and circular aircraft polarization of 2 db ellipticity with worst case orientation. See Note 7 of Amendment A to Technical Note No. A0141.

** Based on paragraph 3.1.1.1.1.2.1 of Specification CP 100009A.

A/RIA Technical Note No. A0146

REVISED SECTOR SCAN PATTERN ANALYSIS

Originator: M. Taylor

Date: July 6, 1966

1. Introduction

The purpose of this technical note is to present a revised determination of the parameters of the sector scan pattern needed to accomplish target acquisition with the nose-mounted A/RIA tracking antenna. A sector scan pattern analysis was previously presented in Technical Note No. 0118, however, revisions are required due to an increase in the receiver frequency acquisition time (see Technical Note No. A0138). As in Technical Note No. 0118, typical areas of target position uncertainty for different mission phases are abstracted from Technical Note No. 0105. While the basic technique of determining the scan parameters has already been developed in Technical Note No. 0118, pertinent details are repeated herein to make the revised analysis self-explanatory.

The analysis assumes that the "possible target" indication which stops the antenna scan is not initiated until receiver frequency search and lock has occurred. In the case of the unified S-band signal, this indication is assumed to be derived from the coherent detector circuit. Actually, the "possible target" signal is derived from a non-synchronous AM detector in the initial tracking receiver design and this may lead to an unacceptable false alarm rate unless corrected.

2. Summary of Analysis

The detailed analysis is given in Section 3 below and the results are tabulated in Tables 1 and 2.

It is anticipated that the present method used in the tracking receiver of deriving the "possible target" indication from a non-synchronous AM detector may lead to unacceptable false alarm rates for unified S-band operation. If a change is required to utilize the coherent detector output for "possible target" indication, the scanning velocity of the antenna beam must be adjusted to allow a sufficient target dwell time in the beam for frequency search and lock.

For normal acquisition at maximum range (1200 N.M.) where the angular uncertainty of predicted target position as well as target angular velocity are small, the required scan area is sufficiently small to allow use of a slow scan rate which is compatible with the presently provided frequency search time (1.23 seconds for the widest single-sided phase-lock loop bandwidth of 1000 cps, $2\ B_{LO} = 2000$ cps).

However, if reacquisition is required under approximately nearest approach conditions where the angular uncertainty of predicted target position as well as target angular velocity are much larger, the required scan area is too large to allow use of the slow scan rate. This situation can be remedied by introducing a new wider phase-lock loop bandwidth with a compatible faster rate of frequency sweep and consequent smaller dwell time requirement. The new phase-lock loop bandwidth recommended is a 4:1 increase over the present value to 4000 cps single-sided or $2\ B_{LO} = 8000$ cps. The total sweep excursion would remain at 370 k/s ± 20% and the sweep rate would be 4.8 mc/sec^2. The antenna scan rate would be adjusted to provide a target dwell time in the antenna beamwidth of 0.23 second which would allow for three frequency search

2. Summary of Analysis (continued)

sweeps giving an acquisition probability of at least 0.999. With this change the acquisition scan times would be as shown in the last column of Table 2.

3. Detailed Analysis

The type of antenna scan pattern used in the A/RIA system is illustrated in Figure 1.

The overlap between beamwidth circles of diameter D (Figure 1) must be such that the common chord length, w, of the overlapping circles will be sufficient to provide a minimum dwell time, Υ, in the beamwidth for frequency acquisition. This value of w determines an effective height, h, of an equivalent rectangular beam given by

$$h = \sqrt{D^2 - w^2} \qquad (1)$$

also $\Upsilon = \frac{w}{V}$ (2)

where V = maximum relative velocity of target and scanning beam

For most efficient scan it is desirable to maximize the rate of area scan which is given by

$$F = hV \qquad (3)$$

Applying standard methods of calculus to determine the conditions for a maximum value of F when Υ is held constant, it is found that the optimum dimensions of the equivalent rectangular beam are

$$h = w = \frac{D}{\sqrt{2}} \qquad (4)$$

For a sector of width W (Figure 1), the distance L that the equivalent rectangular beam must move for one pass is

$$L = W - w \qquad (5)$$

If As is the acceleration which can be applied to start and stop the antenna and Vs is the maximum scan velocity, the time required to accelerate from 0 velocity to Vs or to decelerate from Vs to 0 is $\frac{Vs}{As}$. The distance traveled during the acceleration or deceleration period is

$$\int_0^t Vdt = \int_0^t Ast \cdot dt = \frac{1}{2} Ast^2 = \frac{1}{2} As \left(\frac{Vs}{As}\right)^2 = \frac{V_s^2}{2A_s} \qquad (6)$$

3. Detailed Analysis (continued)

If $\frac{V_s^2}{2A_s} < \frac{L}{2}$, the maximum scan velocity V_s will be reached during the scan and the total time, T_{A1}, required for one azimuth pass is given by

$$T_{A1} = \frac{V_s}{A_s} + \frac{L - 2\frac{V_s^2}{2A_s}}{V_s} + \frac{V_s}{A_s}$$

$$= \frac{2V_s}{A_s} + \frac{L}{V_s} - \frac{V_s}{A_s}$$

$$= \frac{L}{V_s} + \frac{V_s}{A_s} \qquad (7)$$

If $\frac{V_s^2}{2A_s} > \frac{L}{2}$, the maximum scan velocity is not reached during the scan. Instead the antenna will experience acceleration $+ A_s$ for the first half of the scan and $- A_s$ for the second half. The total time, T_{A2}, required for one azimuth pass is then given by

$$\frac{1}{2} A_s \left(\frac{T_{A2}}{2}\right)^2 = \frac{L}{2}$$

or

$$T_{A2} = 2\sqrt{\frac{L}{A_s}} \qquad (8)$$

Similarly, if $\frac{V_s^2}{2A_s} < \frac{h}{2}$, the time, T_{E1}, for the elevation increment is given by

$$T_{E1} = \frac{h}{V_s} + \frac{V_s}{A_s} \qquad (9)$$

and if $\frac{V_s^2}{2A_s} > \frac{h}{2}$, the time T_{E2} for the elevation increment is given by

$$T_{E2} = 2\sqrt{\frac{h}{A_s}} \qquad (10)$$

If n is the number of azimuth sweeps required, the number of elevation increments is n-1. The total time T required for the entire scan pattern is then

$$T = nT_A + (n - 1)\,T_E \qquad (11)$$

where T_A and T_E are determined from Equations (7) or (8) and (9) or (10), respectively.

Considering first, S-band operation where the beamwidth D = 4.5 degrees. This gives

$$h = w = \frac{4.5}{\sqrt{2}} = 3.2 \text{ degrees} \tag{12}$$

For the Apollo injection mission with acquisition at the maximum range point, the initial uncertainty of the predicted azimuth is taken as ± 3.00 degrees and that of the predicted elevation is taken as ± 2.65 degrees (Table 1 of A/RIA Technical Note No. 0105). The maximum target elevation velocity is 0.05 deg/sec for long range conditions (Figure 6 of A/RIA Technical Note No. 0009). The elevation dimensions of the scan must be at least $2 \times 2.65 + 0.05t = 5.3 + 0.05t$ where t is the total scan time. Since this is 5.3 degrees for t = 0, it is obvious that the height h = 3.2 degrees for one azimuth pass is insufficient. Assuming one pass to the right followed by an elevation increment, + h, and then a pass to the left, the pattern height is H = 2 h = 6.4 degrees. Based on the assumed maximum target elevation velocity, the target will remain within this pattern height for a time:

$$t = \frac{6.4 - 5.3}{0.05} = \frac{1.1}{0.05} = 22 \text{ seconds}$$

Since the initial uncertainty of the predicted azimuth is ± 3.00 degrees and the maximum target azimuth velocity is 0.1 deg/sec for long range conditions (from Figure 5 of A/RIA Technical Note No. 0009), the width of the sector must at most be

$$W = 6.0 + 0.1\ t$$

Since the scan time must be less than the 22- second period that the target will remain within the elevation dimension of the pattern, the sector width must at most be

$$W = 6.0 + 0.1 \times 22 = 8.2 \text{ degrees}$$

The distance L that the equivalent rectangular beam must move for one pass is

$$L = W - w = 8.2 - 3.2 = 5.0 \text{ degrees}$$

As shown in Technical Note No. A0138, the widest of the receiver selectable phase-lock loop bandwidths (1000 cps one-sided, $2\ B_{LO}$ = 2000 cps) must be used to provide an adequate frequency search range. The specified sweep excursion and search rate for this loop bandwidth are 370 kc/sec and 300 kc/sec^2, respectively. The sweep period is then

$$\frac{370}{300} = 1.23 \text{ seconds}$$

Since the dwell time in the beam must be at least equal to the time required for one frequency sweep, the maximum relative velocity of the beam and target must not exceed

$$V = \frac{w}{\tau} = \frac{3.2}{1.23} = 2.6 \text{ deg/sec}$$

The maximum beam scan velocity is then

$$Vs = V - \text{target velocity} = 2.6 - 0.1 = 2.5 \text{ deg/sec}$$

Assuming an antenna acceleration capability for both azimuth and elevation motion of at least

$$As = 15 \text{ deg/sec}^2,$$

Since $\frac{Vs^2}{2As} = \frac{(2.5)^2}{2 \times 15} = \frac{6.25}{30} = 0.208 < \frac{L}{2} = \frac{5}{2} = 2.5$

the time required for one azimuth sweep is

$$T_A = \frac{L}{Vs} + \frac{Vs}{As} = \frac{5}{2.5} + \frac{2.5}{15} = 2.0 + 0.167$$

$$= 2.17 \text{ seconds}$$

Since $\frac{Vs^2}{2As} = \frac{(2.5)^2}{2 \times 15} = \frac{6.25}{30} = 0.208 < \frac{h}{2} = \frac{3.2}{2} = 1.6,$

the time required for the elevation increment is

$$T_E = \frac{h}{Vs} + \frac{Vs}{As} = \frac{3.2}{2.5} + \frac{2.5}{15} = 1.28 + 0.167$$

$$= 1.45 \text{ seconds}$$

The tptal time required for the entire scan is

$$\begin{aligned} T &= N\, T_A + (N-1)\, T_E \\ &= 2 \times 2.17 + (2-1)\, 1.45 \\ &= 4.34 + 1.45 \\ &= 5.8 \text{ seconds} \end{aligned}$$

Considering now, the VHF operation where the beamwidth D = 40 degrees,

$$h = w = \frac{40}{\sqrt{2}} = 28.3 \text{ degrees}$$

Since for the Apollo injection mission with acquisition at the maximum range point, the predicted azimuth and elevation uncertainties are only ± 3.00 degrees and ± 2.65 degrees, respectively, it is only necessary to center the VHF beam on the predicted position and no scan is necessary.

The above discussion illustrates the method of determining the sector scan parameters for a particular mission and the results for the S-band case assuming 1 frequency sweep during the dwell time in the beamwidth are tabulated in the first line of Table 1. The frequency sweep rate of 300 kc/sec^2 used in determining the sweep period of 1.23 seconds is such as to insure a probability of frequency acquisition of 0.9 or better for one sweep with the double-sided phase-lock loop bandwidth, $2\ B_{LO}$ = 2000 cps.

It is desired to determine how the probability of acquisition is improved if the dwell time in the antenna beamwidth is increased to permit more than one frequency sweep. This is an example of a binomial probability distribution for which p is the probability of success in one trial and 1-p is the probability of failure. The probability of at least one success in N independent trials is

$$P = 1 - (1 - p)^N \qquad (13)$$

If the probability of frequency acquisition in one sweep (1 trial) is p = 0.9, the probability of acquisition for various numbers of sweeps is as follows:

N = number of sweeps	P = probability of acquisition
1	$1 - (1 - 0.9)^1 = 0.9$
2	$1 - (1 - 0.9)^2 = 0.99$
3	$1 - (1 - 0.9)^3 = 0.999$
4	$1 - (1 - 0.9)^4 = 0.9999$

The scan parameters for the case treated above are recalculated for scanning rates providing time for 2 and 3 frequency sweeps (corresponding to acquisition probabilities of 0.99 and 0.999) and the results are tabulated in the second and third lines of Table 1.

The results of similar analysis for S-band operation for the other mission phases tabulated in Table 1 of A/RIA Technical Note No. 0105 are shown in Table 1 of the present report. It is seen that in four of the mission phases of Table 1, a satisfactory scan pattern is not feasible for the S-band operation. This results from the fact that with the assumed target dwell time in the beamwidth of 1.23 seconds to accomplish frequency acquisition, the relative velocity between the beam and the target cannot exceed $V = \frac{W}{T} = \frac{3.2}{1.23} = 2.6$ deg/sec. For the cases where the target velocity is 1 deg/sec or 0.6 deg/sec, this means that the beam scan velocity cannot exceed $V_s = 2.6 - 1.0 = 1.6$ deg/sec or $2.6 - 0.6 = 2.0$ deg/sec, respectively. In the four cases of Table 1 mentioned, these low scan velocities make it impossible to cover the required scan area in the time that the target will remain within this area.

A remedy for this situation appears to be to provide a wider selectable phase-lock loop bandwidth in the tracking receiver with a compatible higher frequency search rate. It was shown in A/RIA Technical Note No. 0030 that for an assumed phase-lock loop threshold signal-to-noise ratio of 6 db, the VCO sweep rate which results in 90% probability of acquisition in one sweep is given by

$$R_{90} \text{ (cps/sec)} = 0.0965 \, (2 \, B_{LO})^2 \qquad (14)$$

where $2 \, B_{LO}$ = equivalent double-sided noise bandwidth in cps.

It is proposed that the new noise bandwidth be four times the value of the present highest value, or $2 \, B_{LO}$ = 8000 cps. Then from Equation (14),

$$R_{90} = 0.0965 \times 64 \times 10^6 = 6.2 \times 10^6 \text{ cps/sec} = 6.2 \text{ mc/sec}^2$$

If, however, the present sweep rate value of 300 kc/sec² is increased by the square of the ratio of $2 \, B_{LO}$ bandwidths, we have

$$R = 300 \times 10^3 \times (4)^2 = 4.8 \times 10^6 \text{ cps/sec} = 4.8 \text{ mc/sec}^2$$

The later sweep rate is conservatively proposed and should give better than 90% probability of acquisition in one sweep.

Since the present sweep excursion of 370 kc/s ± 20% for the highest bandwidth position was shown to be adequate for all mission phases in Technical Note No. A0138, it is proposed to retain this excursion for the new loop bandwidth. In summary, the new loop bandwidth position would have the following characteristics.

One-sided noise bandwidth	= 4000 cps
Equivalent double-sided noise bandwidth, $2 \, B_{LO}$	= 8000 cps
Total excursion of frequency search sweep	= 370 kc/s ± 20%
Rate of frequency sweep	= 4.8 mc/sec²
Period of 1 frequency sweep	$= \dfrac{370 \times 10^3}{4.8 \times 10^6} = 0.077$ sec
Period of 2 frequency sweeps	= 0.154 sec
Period of 3 frequency sweeps	= 0.231 sec

It is proposed to allow a dwell time in the beam sufficient for three frequency search sweeps, that is 0.23 seconds. This will insure an overall probability of frequency acquisition in excess of 0.999.

Use of the proposed new phase-lock loop bandwidth of 4000 cps ($2 B_{LO}$ = 8000 cps) which is four times the previous value assumed for the acquisition calculations of Table 1 will result in a 6 db reduction in the system threshold sensitivity. However, this bandwidth position would only be used for the shorter range mission phases shown in Table 1 and not for the maximum acquisition range of 1200 N.M. The increase in signal strength for the various shorter ranges shown in Table 1 relative to the signal strengths for 1200 N.M. is as follows:

Reduced range (N. M.)	Increase in signal strength compared to that for 1200 N.M. range (db)
285	12.5
520	7.3
470	8.1
260	13.3

It is seen that in all cases the increase in signal strength for the reduced range exceeds the 6 db loss in system sensitivity. It is concluded that the use of the wider bandwidth position is feasible.

The results of recalculating the scan parameters for the same mission phases treated in Table 1 using the shorter dwell time of 0.23 sedonds instead of 1.23 seconds for all S-band cases other than the maximum range case are given in Table 2. It is seen from Table 2 that a reasonable scan pattern is now feasible for all S-band cases. Table 2 also shows the scan pattern requirements for VHF.

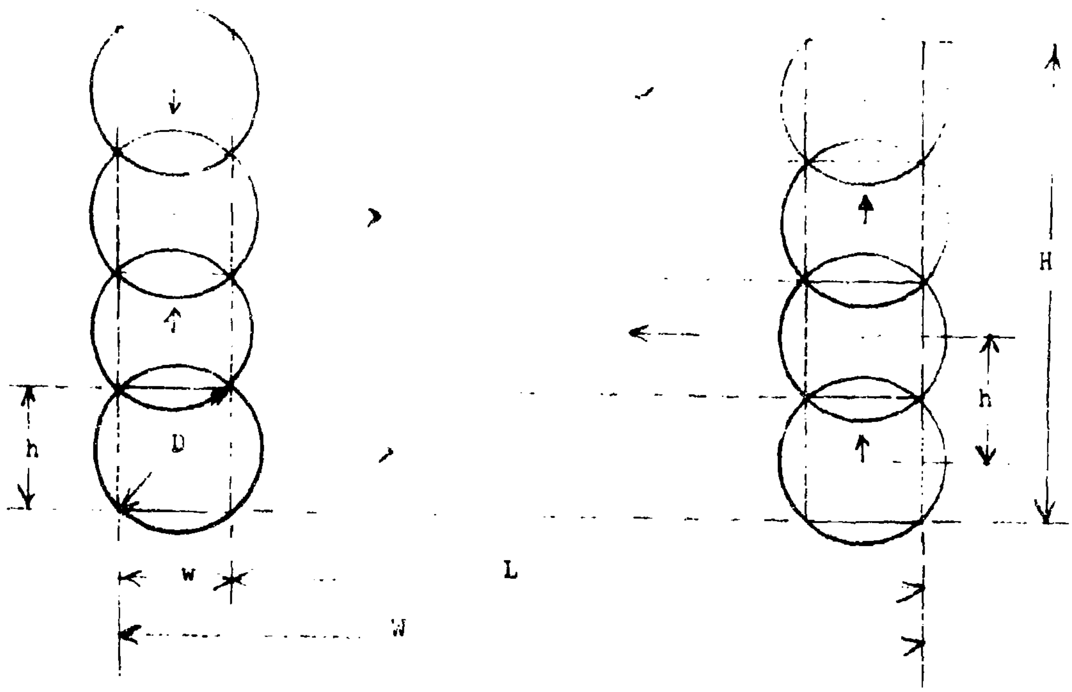


Figure 1. Rectangular Scan Pattern With Step Increase in Elevation at Ends of Azimuth Sweep

D = diameter of beam in degrees at 3 DB down

h = height of equivalent rectangular beam in degrees

w = width of equivalent rectangular beam in degrees

V = maximum relative velocity of target and scanning beam

τ = minimum dwell time for target in equivalent rectangular beam

W = width (azimuth) of sector to be scanned in degrees

L = distance moved by beam in one horizontal scan in degrees

$h = \sqrt{D^2 - w^2}$

$\tau = \frac{w}{V}$

V_s = azimuth scan velocity

A_s = acceleration of mount

TABLE 1 ACQUISTION SCAN PARAMETERS FOR

MISSION	PHASE	FREQUENCY BAND	DOUBLE-SIDED PHASE-LOCK LOOP BANDWIDTH $2B_{Lo}$ (CPS)	TIME FOR 1 FREQUENCY SWEEP (SECONDS)	NUMBER OF FREQUENCY SWEEPS	REQUIRED DWELL TIME IN EFFECTIVE SQUARE BEAM (SECONDS)	PROBABILITY OF FREQUENCY ACQUISITION	ERROR IN PREDICTED AZIMUTH (DEG)	ERROR IN PREDICTED ELEVATION (DEG)	MAXIMUM TARGET AZIMUTH VELOCITY (DEG/SEC)	MAXIMUM TARGET ELEVATION VELOCITY (DEG/SEC)	MAXIMUM SCAN VELOCITY V_S (DEG./SEC)	NUM[illegible]
APOLLO INJECTION	MAXIMUM RANGE RANGE: 1300 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±30 N.M.	S-BAND	2000	1.23	1	1.23	0.9	± 3.00	± 2.65	0.1	0.05	2.5	2
		"	"	"	2	2.46	0.99	"	"	"	"	1.2	[illegible]
		"	"	"	3	3.69	0.999	"	"	"	"	0.8	[illegible]
APOLLO INJECTION	SPACECRAFT AT NEAREST APPROACH RANGE: 285 N.M. POSITION ERRORS: AIRCRAFT: ±10 N.M. SPACECRAFT: ±0.5 N.M.	S-BAND	2000	1.23	1	1.23	0.9	±3.18	±2.52	1.0	0.2	←	
APOLLO INJECTION	SPACECRAFT AT NEAREST APPROACH RANGE: 255 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±0.5 N.M.	S-BAND	2000	1.23	1	1.23	0.9	±6.4	±2.9	1.0	0.2	←	
APOLLO INJECTION	SPACECRAFT AT NEAREST APPROACH RANGE: 285 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±30 N.M.	S-BAND	2000	1.23	1	1.23	0.9	±7.5	±4.8	1.0	0.2	←	
APOLLO REENTRY	ACQUISITION 1 MINUTE PRIOR TO REENTRY RANGE: 520 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±30 N.M.	S-BAND	2000	1.23	1	1.23	0.9	±4.60	±3.27	0.4	0.1	2.2	3
APOLLO REENTRY	ACQUISITION ON EXIT FROM FIRST BLACKOUT RANGE: 470 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±50 N.M. FOR AZ AND ±30 N.M. FOR EL	S-BAND	2000	1.23	1	1.23	0.9	±7.40	±4.45	0.35	0.1	2.3	3
APOLLO REENTRY	ACQUISITION ON EXIT FROM SECOND BLACKOUT RANGE: 350 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±150 N.M. FOR AZ AND ±30 N.M. FOR EL	S-BAND	2000	1.23	1	1.23	0.9	±34	± 5	0.6	0.05	←	

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TABLE 1. ACQUISITION SCAN PARAMETERS FOR S-BAND USING PRESENTLY AVAILABLE PHASE-LOCK LOOP BANDWIDTH

TIME FOR FREQUENCY SWEEP (SECONDS)	NUMBER OF FREQUENCY SWEEPS	REQUIRED DWELL TIME IN EFFECTIVE SQUARE BEAM (SECONDS)	PROBABILITY OF FREQUENCY ACQUISITION	ERROR IN PREDICTED AZIMUTH (DEG.)	ERROR IN PREDICTED ELEVATION (DEG.)	MAXIMUM TARGET AZIMUTH VELOCITY (DEG/SEC)	MAXIMUM TARGET ELEVATION VELOCITY (DEG/SEC)	MAXIMUM SCAN VELOCITY V_s (DEG./SEC)	NUMBER OF AZIMUTH CYCLES (M)	ELEVATION DIMENSION OF PATTERN H (DEG.)	AZIMUTH DIMENSION OF PATTERN W (DEG.)	LENGTH OF AZIMUTH SWEEP L (DEG.)	TIME FOR ONE AZIMUTH SWEEP T_A (SEC.)	TIME FOR ONE ELEVATION INCREMENT T_E (SEC.)	TOTAL ACQUISITION TIME T (SEC.)
1.23	1	1.23	0.9	±3.00	±2.65	0.1	0.05	2.5	2	6.4	8.3	5.0	2.17	1.45	5.8
"	2	2.46	0.99	"		"		1.2	"	"	"	"	4.25	2.75	11.2
"	3	3.69	0.999	"	"	"	"	0.8	"	"	"	"	6.20	4.05	16.6
1.23	1	1.23	0.9	±3.15	±2.82	1.0	0.2	←			NOT FEASIBLE →				
1.23	1	1.23	0.9	±6.4	±2.9	1.0	0.2	←			NOT FEASIBLE →				
1.23	1	1.23	0.9	±7.5	±4.5	1.0	0.2	←			NOT FEASIBLE →				
1.23	1	1.23	0.9	±4.60	±3.27	0.4	0.1	2.2	3	9.6	21.4	18.2	8.42	1.40	28.5
1.23	1	1.23	0.9	±7.40	±2.45	0.25	0.1	2.3	3	9.6	21.6	18.4	8.0	1.5	29
1.23	1	1.23	0.9	±34	±5	9.6	0.05	←			NOT FEASIBLE →				

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TABLE 2. ACQUISITION SCAN PARAMETERS ASSUMING AVA

MISSION	PHASE	FREQUENCY BAND	DOUBLE-SIDED PHASE-LOCK LOOP BANDWIDTH $2B_L$ (CPS)	TIME FOR 1 FREQUENCY SWEEP (SECONDS)	NUMBER OF FREQUENCY SWEEPS	REQUIRED DWELL TIME (AND EFFECTIVE SEARCH BEAM) (SECONDS)	PROBABILITY OF FREQUENCY ACQUISITION	ERROR IN PREDICTED AZIMUTH (DEG.)	ERROR IN PREDICTED ELEVATION (DEG.)	MAXIMUM TARGET AZIMUTH VELOCITY (DEG./SEC.)	MAXIMUM TARGET ELEVATION VELOCITY (DEG./SEC.)	MAXIMUM SCAN VELOCITY V_s (DEG./SEC.)	NUMBER OF AZIMUTH SWEEPS (n)
APOLLO INJECTION	MAXIMUM RANGE TRACKING RANGE: 1800 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±20 N.M.	S-BAND	2000	1.23	1	1.23	0.9	±3.00	±2.65	0.1	0.05	2.5	2
			"	"	2	2.46	0.99	"	"	"	"	1.2	"
			"	"	3	3.69	0.999	"	"	"	"	0.8	"
		VHF	NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED
			"	"	2	0.50	0.99	"	"	"	"	"	"
			"	"	3	0.75	0.999	"	"	"	"	"	"
APOLLO INJECTION	SPACECRAFT AT NEAREST APPROACH RANGE: 333 N.M. POSITION ERRORS: AIRCRAFT: ±[illegible] N.M. SPACECRAFT: ±[illegible] N.M.	S-BAND	8000	0.077	1	0.077	0.9	±3.19	±2.52	1.0	0.2	EXCEEDS SCANNER CAPABILITY	—
			"	"	2	0.154	0.99	"	"	"	"	"	—
			"	"	3	0.231	0.999	"	"	"	"	12.9	2
		VHF	NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED
			"	"	2	0.50	0.99	"	"	"	"	"	"
			"	"	3	0.75	0.999	"	"	"	"	"	"
APOLLO INJECTION	SPACECRAFT AT NEAREST APPROACH RANGE: 283 N.M. POSITION ERRORS: AIRCRAFT: ±20 N.M. SPACECRAFT: ±4.5 N.M.	S-BAND	1600	0.077	1	0.077	0.9	±6.4	±3.9	1.0	0.2	EXCEEDS SCANNER CAPABILITY	—
			"	"	2	0.154	0.99	"	"	"	"	"	—
			"	"	3	0.231	0.999	"	"	"	"	12.9	2
		VHF	NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED
			"	"	2	0.50	0.99	"	"	"	"	"	"
			"	"	3	0.75	0.999	"	"	"	"	"	"
APOLLO INJECTION	SPACECRAFT AT NEAREST APPROACH RANGE: 285 N.M. POSITION ERRORS: AIRCRAFT: ±30 N.M. SPACECRAFT: ±20 N.M.	S-BAND	1000	0.077	1	0.077	0.9	±7.5	±4.3	1.0	0.2	EXCEEDS SCANNER CAPABILITY	—
			"	"	2	0.154	0.99	"	"	"	"	"	—
			"	"	3	0.231	0.999	"	"	"	"	12.9	4
		VHF	NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED
			"	"	2	0.50	0.99	"	"	"	"	"	"
			"	"	2	0.75	0.999	"	"	"	"	"	"

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TABLE 2. ACQUISITION SCAN PARAMETERS ASSUMING AVAILABILITY OF WIDER PHASE-LOCK LOOP BANDWIDTHS FOR [illegible]

[illegible]	TIME FOR 1 FREQUENCY SWEEP (SECONDS)	NUMBER OF FREQUENCY SWEEPS	EXPECTED MEAN TIME FROM EFFECTIVE SEARCH BEAM (SECONDS)	PROBABILITY OF FREQUENCY ACQUISITION	ERROR IN PREDICTED AZIMUTH (DEG.)	ERROR IN PREDICTED ELEVATION (DEG.)	MAXIMUM TARGET AZIMUTH VELOCITY (DEG./SEC.)	MAXIMUM TARGET ELEVATION VELOCITY (DEG./SEC.)	MAXIMUM SCAN VELOCITY V_s (DEG./SEC.)	NUMBER OF AZIMUTH SWEEPS (N)	ELEVATION DIMENSION OF PATTERN H (DEG.)	AZIMUTH DIMENSION OF PATTERN W (DEG.)	LENGTH OF AZIMUTH SWEEP L (DEG.)	TIME FOR ONE AZIMUTH SWEEP T_A (SEC.)	TIME FOR ONE ELEVATION INCREMENT T_E (SEC.)	TOTAL ACQUISITION TIME T (SEC.)
1000	1.53	1	1.53	0.9	± .03	± 2.68	0.1	0.05	2.5	2	6.4	8.2	8.0	2.17	1.45	5.8
[illegible]	"	2	3.06	0.99	"	"	"	"	1.2	"	"	"	"	4.35	2.75	11.2
"	"	3	3.69	0.999	"	"	"	"	0.8	"	"	"	"	6.36	4.05	16.6
NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED	28.2	56.3	—	—	—	0.25
"	"	2	0.50	0.99	"	"	"	"	"	"	"	"	—	—	—	0.50
"	"	3	0.75	0.999	"	"	"	"	"	"	"	"	—	—	—	0.75
2000	0.077	1	0.077	0.9	± 3.18	± 2.52	1.0	0.2	EXCEEDS SCANNER CAPABILITY	—	—	—	—	—	[illegible]	[illegible]
"	"	2	0.154	0.99	"	"	"	"	"	—	—	—	—	—	—	—
"	"	3	0.231	0.999	"	"	"	"	12.9	2	6.4	13.2	10.0	1.63	0.92	4.2
NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED	25.3	38.3	—	—	—	0.25
"	"	2	0.50	0.99	"	"	"	"	"	"	"	"	—	—	—	0.50
"	"	3	0.75	0.999	"	"	"	"	"	"	"	"	—	—	—	0.75
5000	0.077	1	0.077		± 6.4	± 3.9	1.0	0.2	EXCEEDS SCANNER CAPABILITY	—	—	—	—	—	—	—
"	"	2	0.154	0.99	"	"	"	"	"	—	—	—	—	—	—	—
"	"	3	0.231	0.999	"	"	"	"	13.9	2	9.6	22.1	19.6	2.31	0.95	9.0
NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED	38.2	34.3	—	—	—	0.25
"	"	2	0.50	0.99	"	"	"	"	"	"	"	"	—	—	—	0.50
"	"	3	0.75	0.999	"	"	"	"	"	"	"	"	—	—	—	0.75
8000	0.077	1	0.077	0.9	± 7.5	± 4.8	1.0	0.2	EXCEEDS SCANNER CAPABILITY	—	—	—	—	—	—	—
"	"	2	0.154	0.99	"	"	"	"	"	—	—	—	—	—	—	—
"	"	3	0.231	0.999	"	"	"	"	12.9	4	12.8	31.0	27.8	3.02	0.92	14.8
NOT APPLICABLE	0.25	1	0.25	0.9	"	"	"	"	NO SCAN REQUIRED	NONE REQUIRED	28.7	28.2	—	—	—	0.25
"	"	2	0.50	0.99	"	"	"	"	"	"	"	"	—	—	—	0.50
"	"	3	0.75	0.999	"	"	"	"	"	"	"	"	—	—	—	0.75

B

A/RIA TECHNICAL NOTE A0164

POLARIZATION ROTATION

OF THE A/RIA ANTENNA

Originator

A. Moeller

References

1. A/RIA Technical Note TN 0053

June 5, 1967

The A/RIA dish rolls about its axis as the antenna scans off axis as a result of the canted mount configuration. The VHF polarization orientation will therefore be a function of the following parameters.

(1) Azimuth scan angle

(2) Elevation tilt angle

(3) Aircraft roll

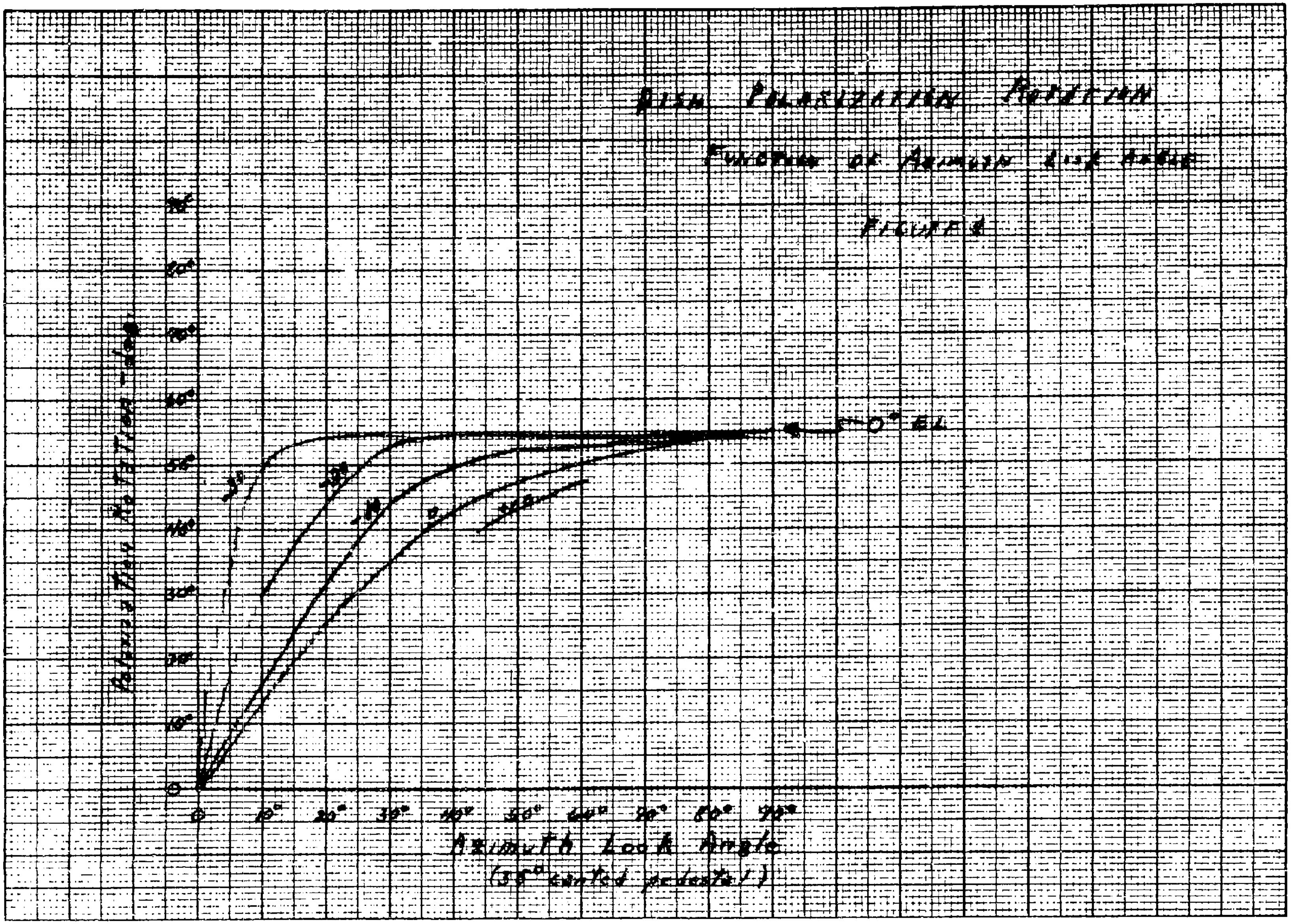
The degree of polarization rotation for the above parameters has been determined by means of the coordinate transformation chart giving in Tech Note 0053 and measurements on a mechanical scale model of the canted antenna mount and dish.

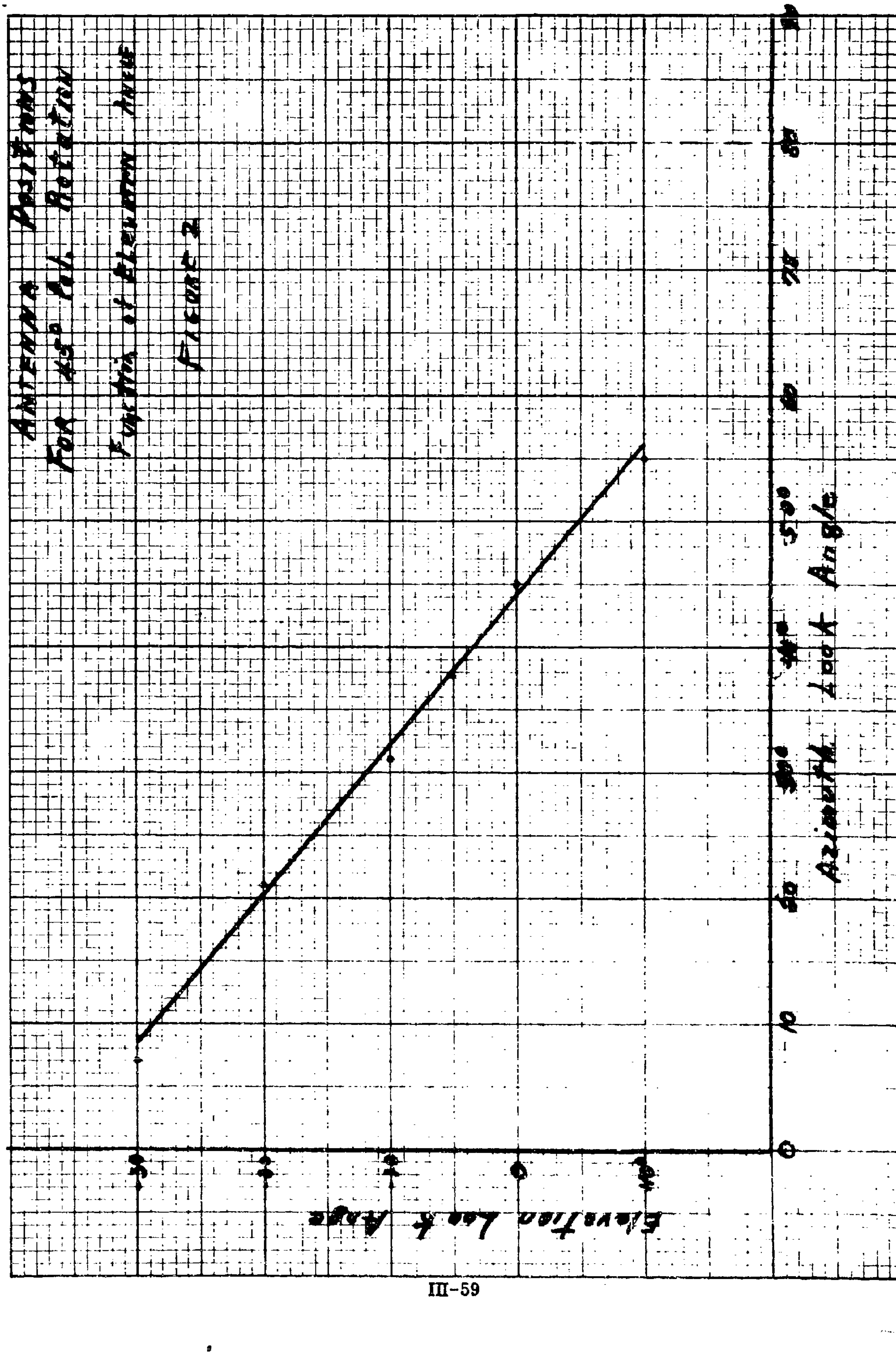
The change in polarization as a function of azimuth scan angle and elevation tilt is shown in Figure 1. Assuming 0 degrees elevation tilt and roll, the A/RIA antenna VHF polarization changes non-linearly from vertical (or horizontal) at 0° azimuth scan angle, to ±45° slant linear polarization at ±45° azimuth scan angle, and to ±55° slant linear polarization at ±90° azimuth scan angle.

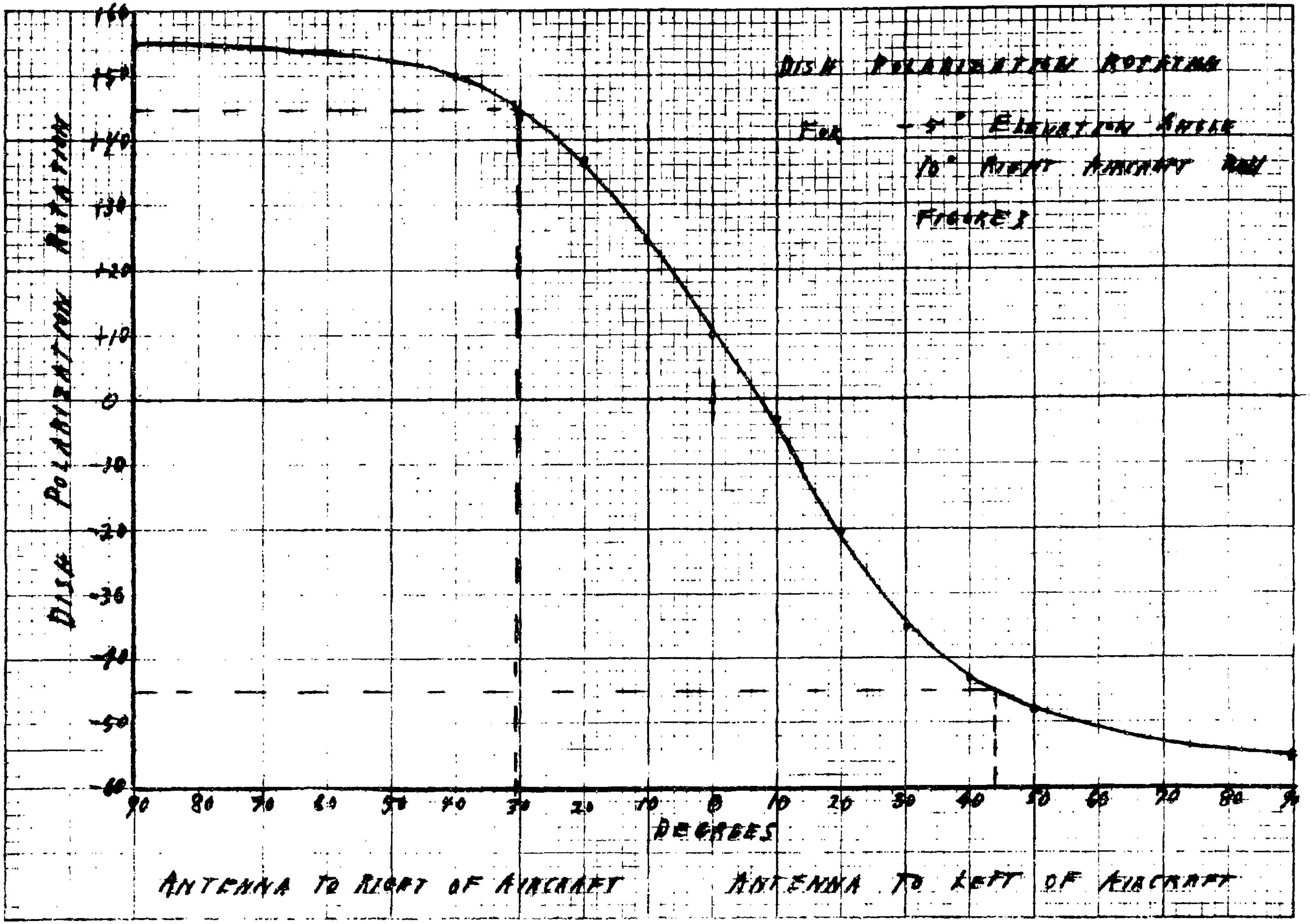
The azimuth and corresponding elevation scan angles which result in a 45° polarization orientation of the A/RIA dish are shown in Figure 2. It can be seen that as the elevation tilt angle becomes more negative the corresponding azimuth scan angle for a 45° polarization orientation decreases.

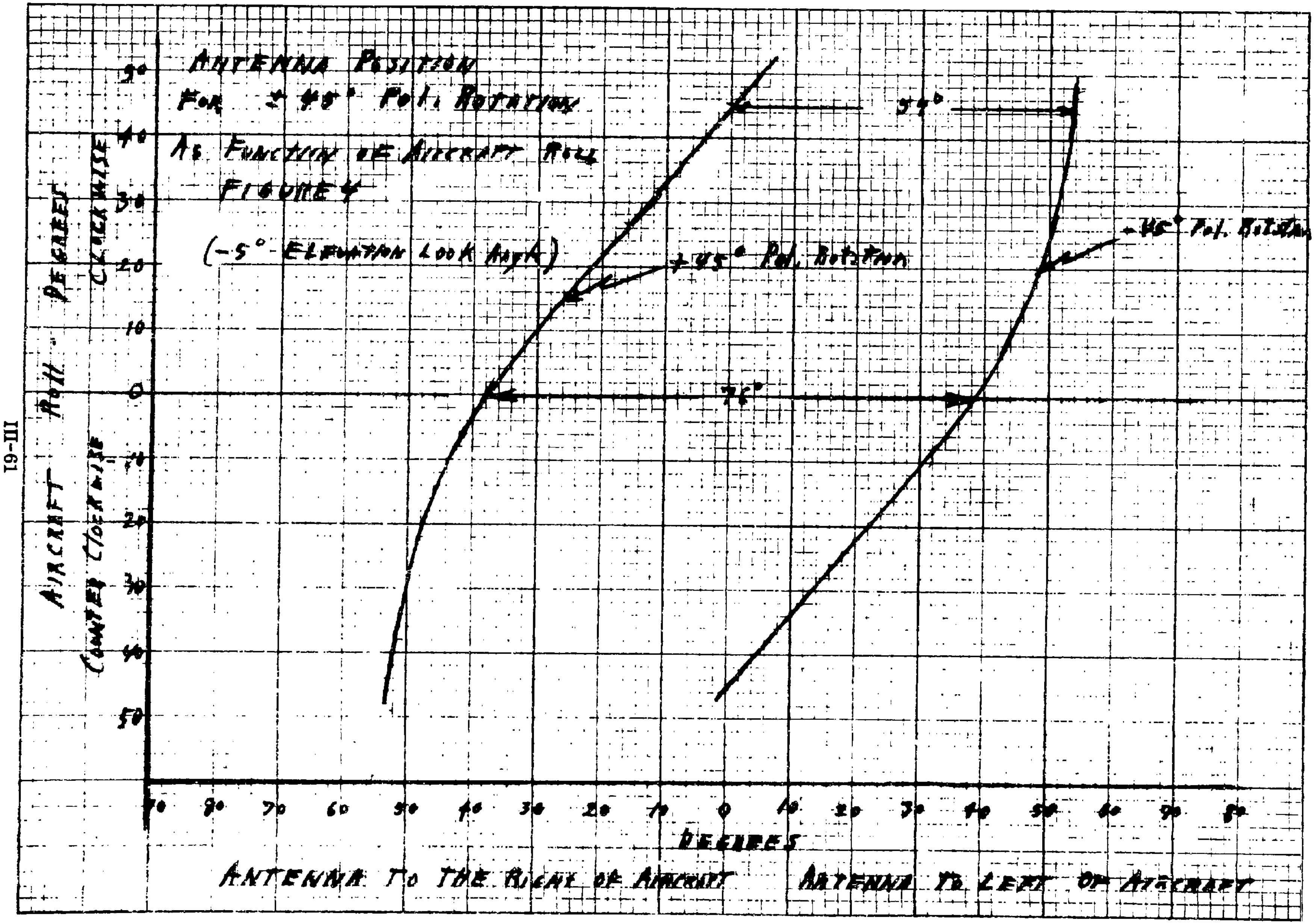
The effect of aircraft roll is shown in Figure 3 and 4. Figure 3 shows the dish polarization rotation for a -5 degree elevation tilt angle and a 10° right aircraft roll. The 0 degree (vertical polarization) point occurs at an azimuth angle of 8 degrees left, while that ±45 degree polarization points occurs at azimuth scan angles of

30 degrees right and 44 degrees left respectively. Figure 4 shows the antenna azimuth positions for ±45 degree polarization as a function of aircraft roll. As the aircraft roll increases the ±45 degree polarization positions become assymmetrical about the 0 degree azimuth scan position and their separations decrease. For a 30 degree clockwise roll a ±45 degrees polarization rotation of the dish occurs at azimuth scan angle of 12 degrees right and 51 degrees left of the aircraft heading respectively. This condition is nearly identical to that observed in the category 2 Test #14, Data Run #3 (Evaluation of tracking characteristics at VHF slant linear polarization -45°). This would explain the assymmetrical location of the polarization nulls observed during this test as the aircraft was in a tight turn when these measurements were taken.


Function of Azimuth Look Angle
0° EL
0
10°
20°
30°
40°
50°
60°
70°
80°
Azimuth Look Angle


ANTENNA POSITIONS
For 45° Pol. Rotation
Function of Elevation Angle
Figure 2
Azimuth Look Angle
Elevation Look Angle


DISH POLARIZATION ROTATION
FOR -5° ELEVATION ANGLE
10° RIGHT AIRCRAFT ROLL
DISH POLARIZATION ROTATION
DEGREES
ANTENNA TO RIGHT OF AIRCRAFT
ANTENNA TO LEFT OF AIRCRAFT


ANTENNA POSITION
FOR ± 45° POL. ROTATION
AS FUNCTION OF AIRCRAFT ROLL
FIGURE 4
(-5° ELEVATION LOOK ANGLE)
+45° POL. ROTATION
-45° POL. ROTATION
54°
75°
AIRCRAFT ROLL - DEGREES
CLOCKWISE
COUNTER CLOCKWISE
DEGREES
ANTENNA TO THE RIGHT OF AIRCRAFT
ANTENNA TO LEFT OF AIRCRAFT

A/RIA Technical Note No. A0165

ANALYSIS OF THE AMPLITUDE SPECTRUM
OF A
FM WAVE MODULATED BY A TWO TONE SIGNAL

Originator: S. M. Quintiliani
October 20, 1957

Introduction.

The purpose of this technical note is to analyze the amplitude spectrum of a PM wave modulated by a two tone signal. This analysis is the result of an investigation, predicated upon the following problem #20, (VHF/UHF Signal Generator Qualification), and will be used to determine if the spectrum produced by the VHF/UHF Signal Generator when operated in the U.S.B. format contains the desired and predicted sideband components or spurious signals.

Analysis of the Amplitude Spectrum of a PM Wave Modulated by a Two Tone Signal.

In general an angle modulated sinusoidal carrier wave can be expressed as:

$$M(t) = A_c \cos \left[W_c t + \phi(t)\right]$$

where A_c - Sinusoidal carrier, peak amplitude

W_c - Sinusoidal carrier, center angular frequency

$\phi(t)$ - Instantaneous phase deviation

For a PM Wave, the instantaneous phase deviation is directly proportional to the modulating voltage amplitude: $\phi(t) = k\ e_m(t)$

For the case of a sinusoidal modulating waveform:

$$\phi(t) = k\ A_m \cos W_m t$$

where A_m - Modulating signal peak amplitude

W_m - Modulating signal angular frequency

k - proportionality constant

The modulation index (X) is defined as the instantaneous peak phase deviation. For the above case: $X = k A_m$

Consider the case where the modulating signal consists of two sinusoidal signals of the form:

$$e_m(t) = \underbrace{A_1 \cos W_1 t}_{\text{Tone \#1}} + \underbrace{A_2 \cos W_2 t}_{\text{Tone \#2}}$$

Therefore $\phi(t) = k_1 \ (A_1 \cos W_1 t + A_2 \cos W_2 t)$

and $M(t) = A_c \cos (W_c t + X_1 \cos W_1 t + X_2 \cos W_2 t)$

where X_1 is defined as the modulation index of Tone #1

X_2 is defined as the modulation index of Tone #2

The above equation has been solved in "Transmission Systems for Communications" - Bell Telephone Laboratories, 1964 - Chapter 19, pp 447-449:

$$M(t) = A_c \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} J_n(X_1) \cdot J_m(X_2) \cos \left[(W_c + nw_1 + mw_2)t + \frac{(n+m)\pi}{2} \right]$$

Where $J_n(X_1)$ & $J_m(X_2)$ are Bessel functions of the first kind; of nth order & of argument X_1, and mth order & of argument X_2, respectively.

The equation indicates that, in general, not only will there be side-band components displaced from the carrier by all possible multiples of the individual modulating frequencies, but also components displaced by all possible sums and differences of multiples of the modulating frequencies.

For the condition, $X_1 = 1.10$ radian & $X_2 = 0.54$ radian with $f_1 = 1.024$ MHz & $f_2 = 1.250$ MHz, respectively:

$$M(t) = A_c \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} J_n(1.1) \ J_m(.54) \cos \left[2\pi \ 10^6 (f_c + 1.024n + 1.25m)t + \frac{(n+m)\pi}{2} \right]$$

Normalizing the above equation with respect to the unmodulated carrier peak amplitude ($A_c = 1$) and assuming $f_c = 50$ MHz, the amplitude spectrum is as tabulated in Table 1. This table includes only the third order components that are within a bandwidth of $f_o \pm 2f_2$ and are greater in amplitude than 1% of the unmodulated carrier.

Table 2 contains a listing of the pertinent Bessel coefficients.

See Figure 1 for a plot of the amplitude spectrum.

TABLE 1

n	m	$f_o+nf_1+mf_2$ (MHz)	$\lvert J_n(1.1)\rvert \cdot \lvert J_m(.54)\rvert$	DB Down from Unmod. carrier
0	0	50.000	0.6681	3.50
1	0	51.024	0.4372	7.18
-1	0	48.976	0.4372	7.18
0	1	51.250	0.1873	14.54
0	-1	48.750	0.1873	14.54
2	0	52.048	0.1273	17.90
-2	0	47.952	0.1273	17.90
1	1	52.274	0.1226	18.24
-1	1	50.226	0.1226	18.24
1	-1	49.774	0.1226	18.24
-1	-1	47.726	0.1226	18.24
2	-1	50.798	0.0357	28.94
-2	1	49.202	0.0357	28.94
0	2	52.500	0.0256	31.84
0	-2	47.500	0.0256	31.84
-1	2	51.476	0.0168	35.50
1	-2	48.524	0.0168	35.50

TABLE 2

Reference: Jahnke & Emde - "Tables of Functions"
Dover Publications, 1945,
pp. 128, 156, 157 & 182.

n	$J_n(1.10)$	m	$J_m(0.54)$
0	0.7196	0	0.9284
1	0.4709	1	0.2603
2	0.1371	2	0.0356

* $J_2(X)$ values computed using relation found in above reference on p. 128:

$$J_p(X) = \frac{(1/2X)^p}{p!} \quad A_p(X)$$

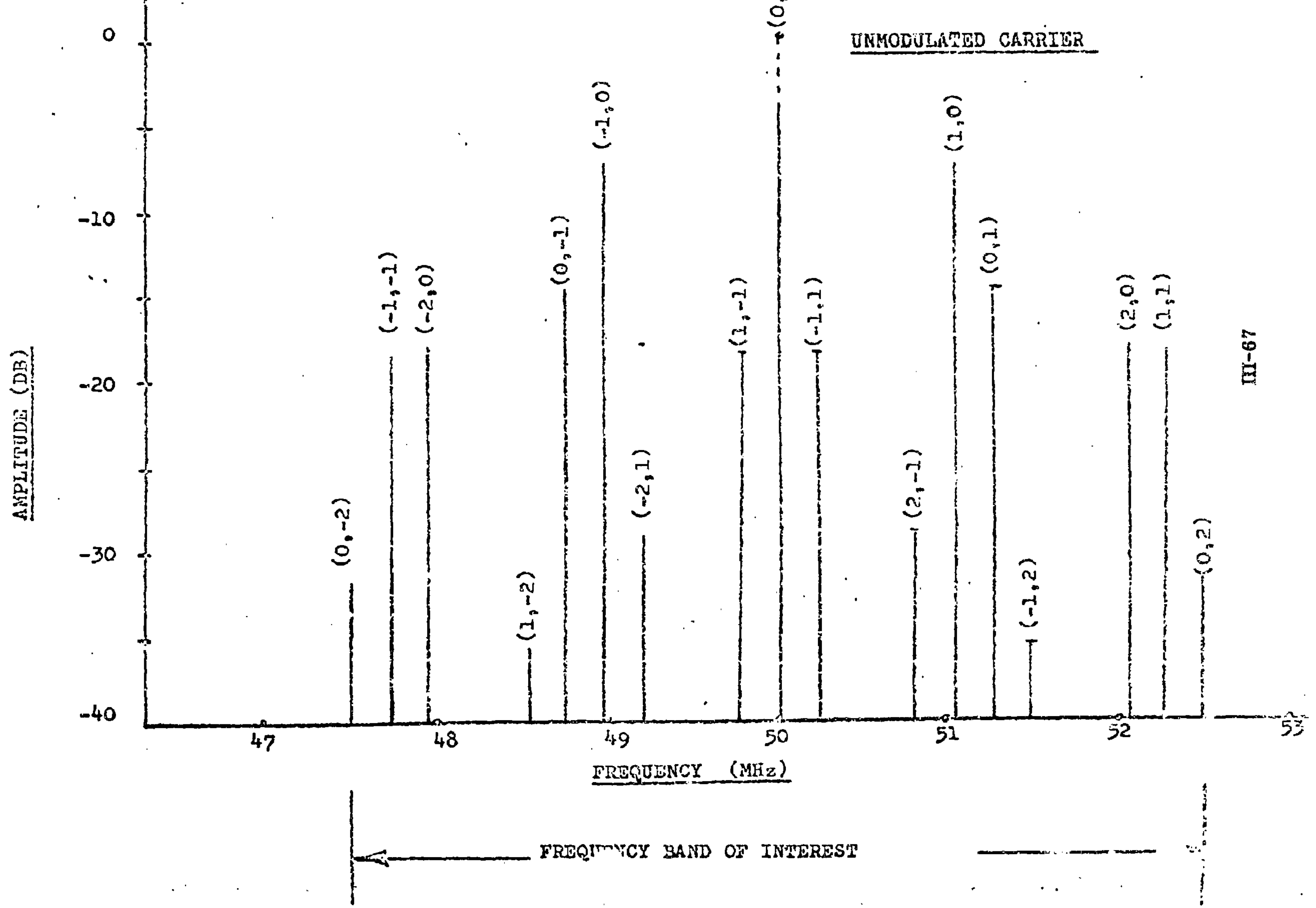
and table of $A_2(X)$ on page 182.

PM - TWO TONE

FIGURE 1 - AMPLITUDE SPECTRUM

$X_1 = 1.10 \quad X_2 = 0.54$

$f_1 = 1.024$ MHz $\quad f_2 = 1.250$ MHz



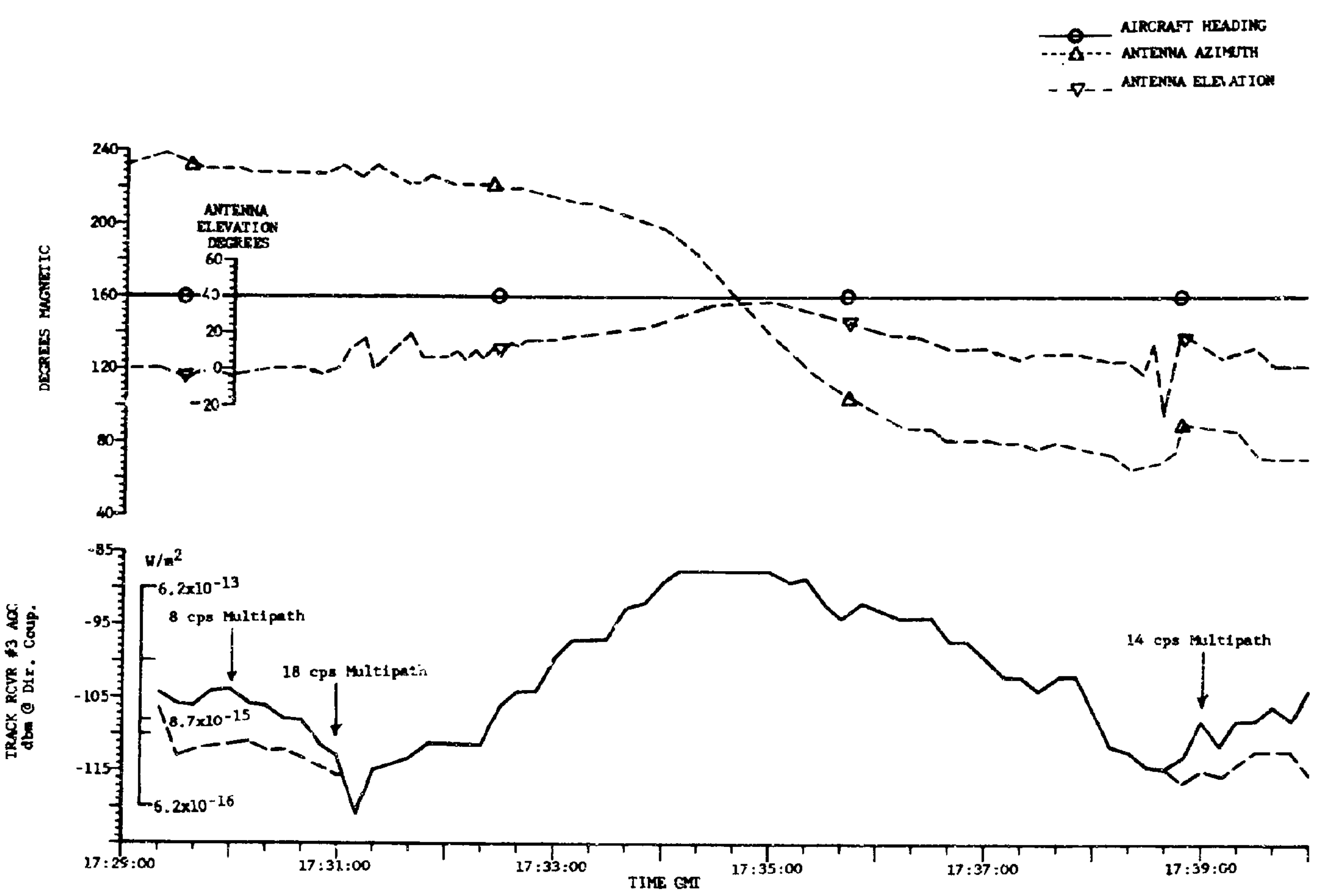


FIGURE III-1. SIGNAL LEVEL VS ANTENNA POINTING ANGLE FOR GEMINI ORBIT 13

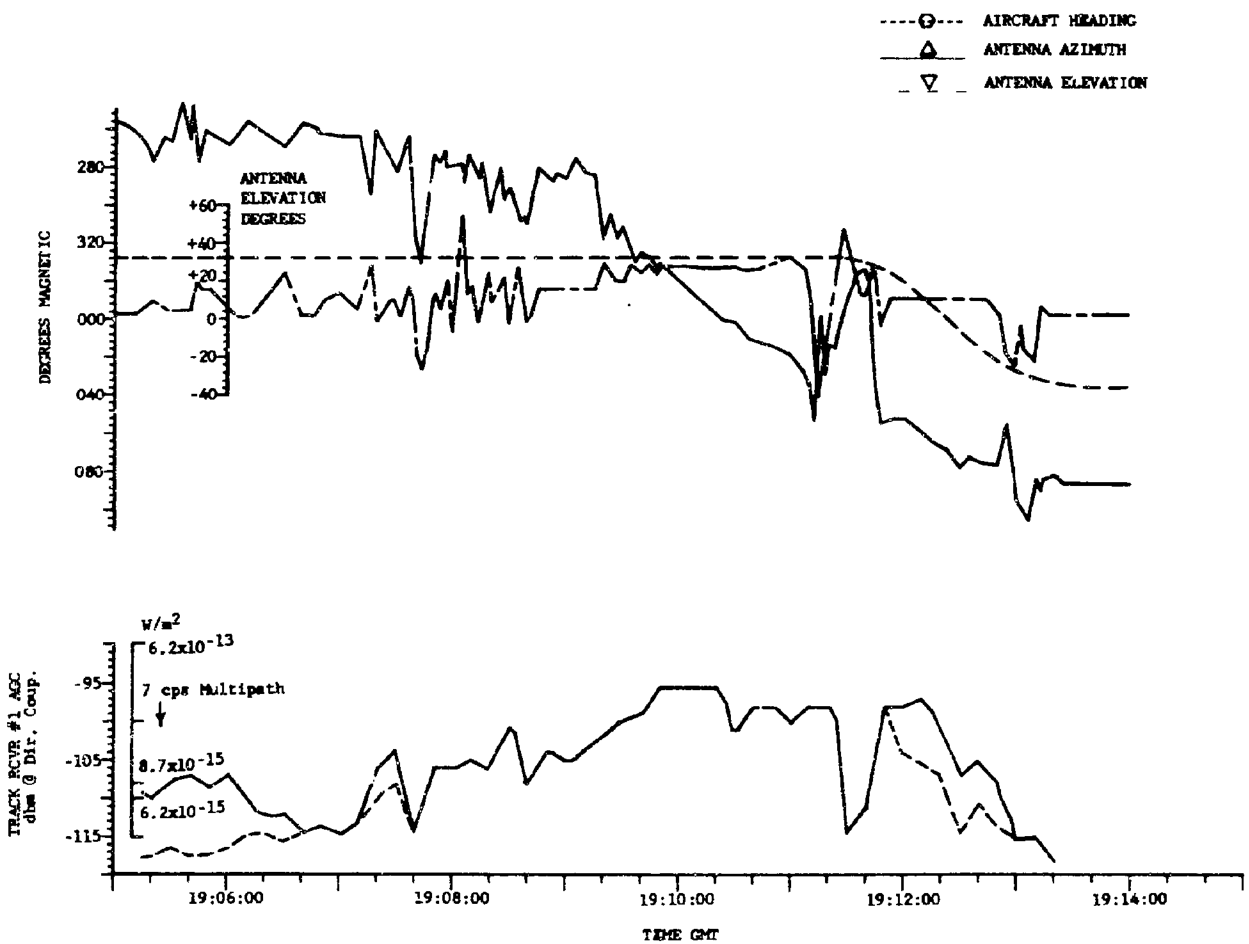


FIGURE III-2. SIGNAL LEVEL VS ANTENNA POINTING ANGLE FOR GEMINI ORBIT 14

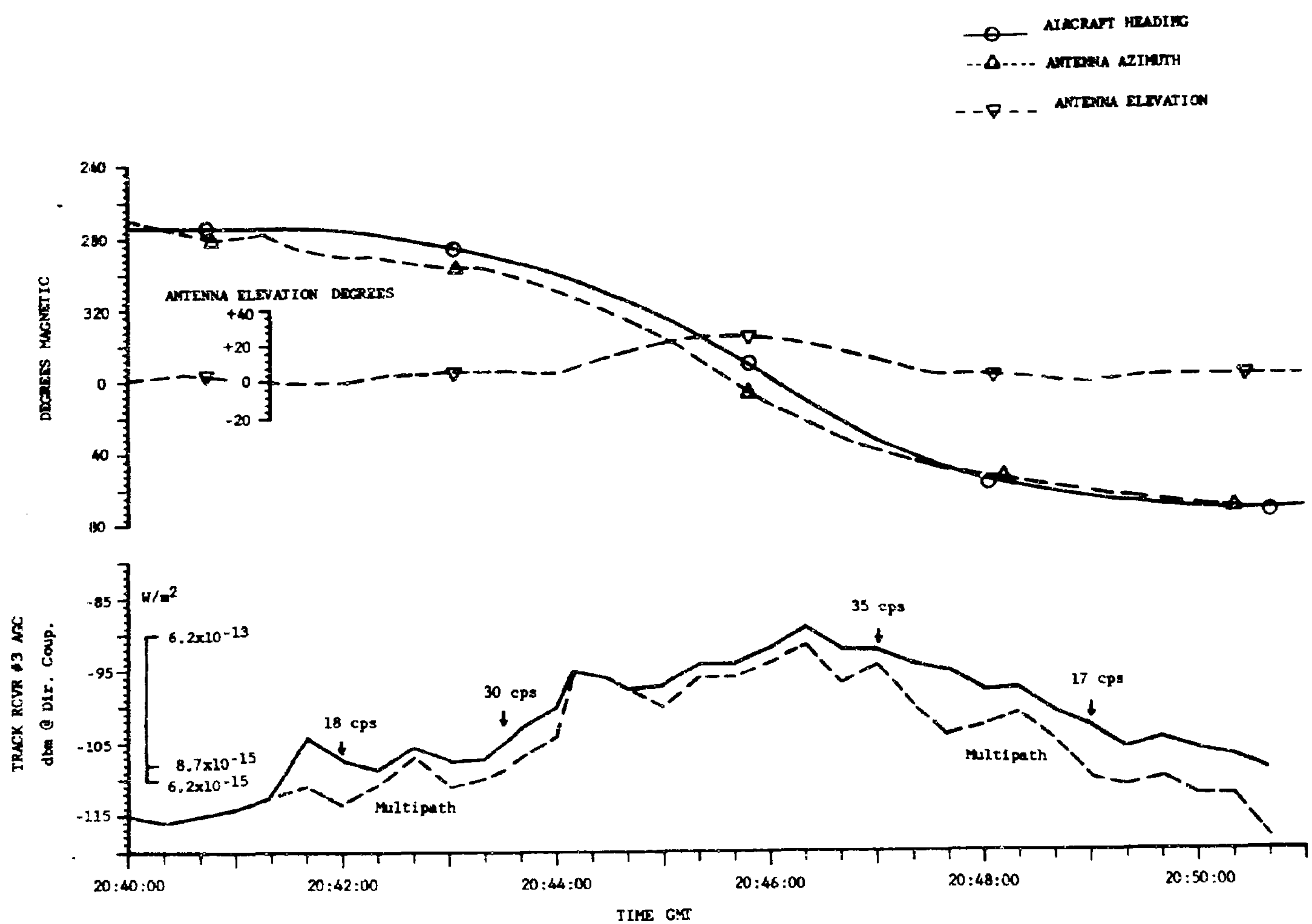


FIGURE III-3. SIGNAL LEVEL VS ANTENNA POINTING ANGLE FOR GEMINI ORBIT 15

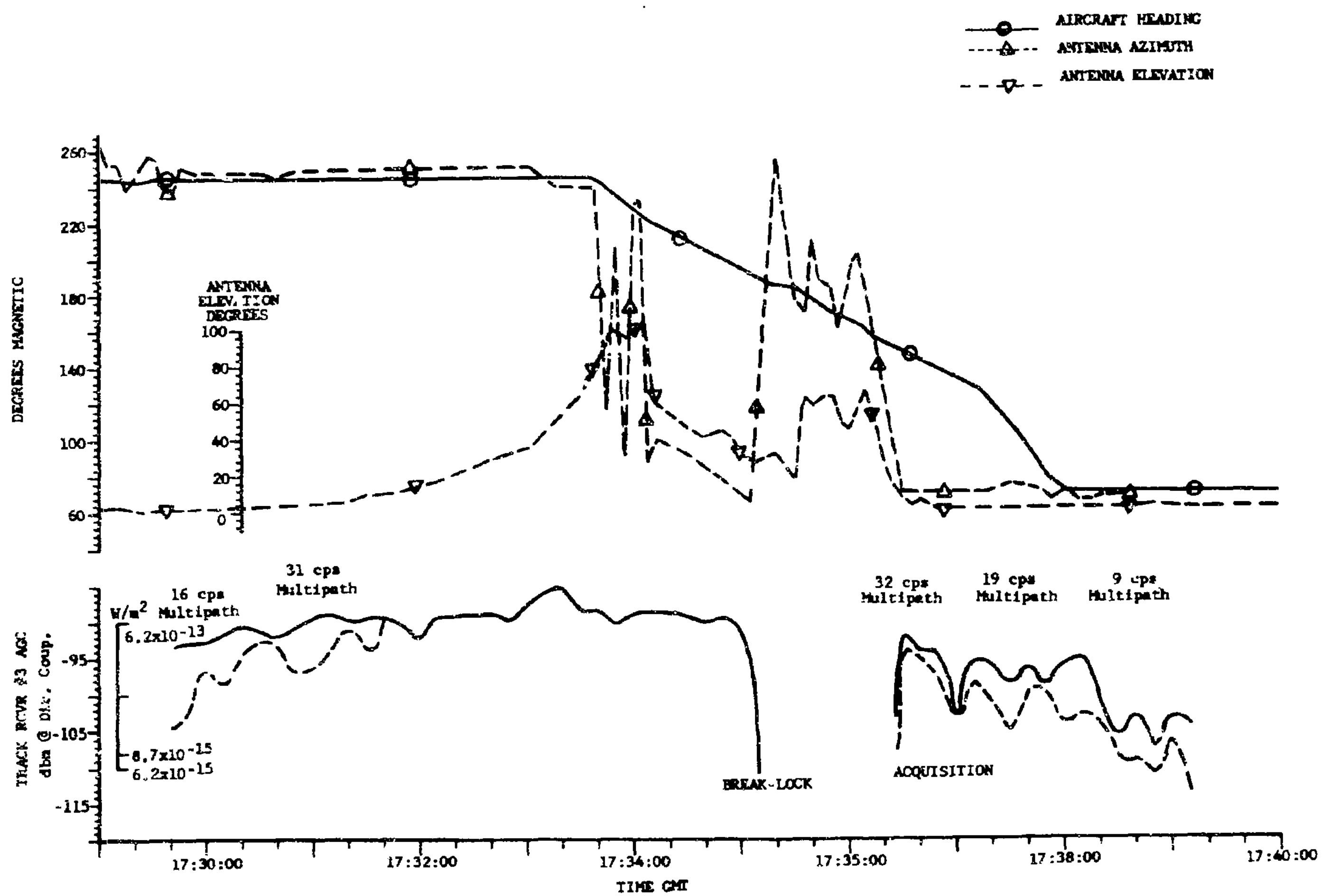


FIGURE III-4. SIGNAL LEVEL VS ANTENNA POINTING ANGLE FOR GEMINI ORBIT 43

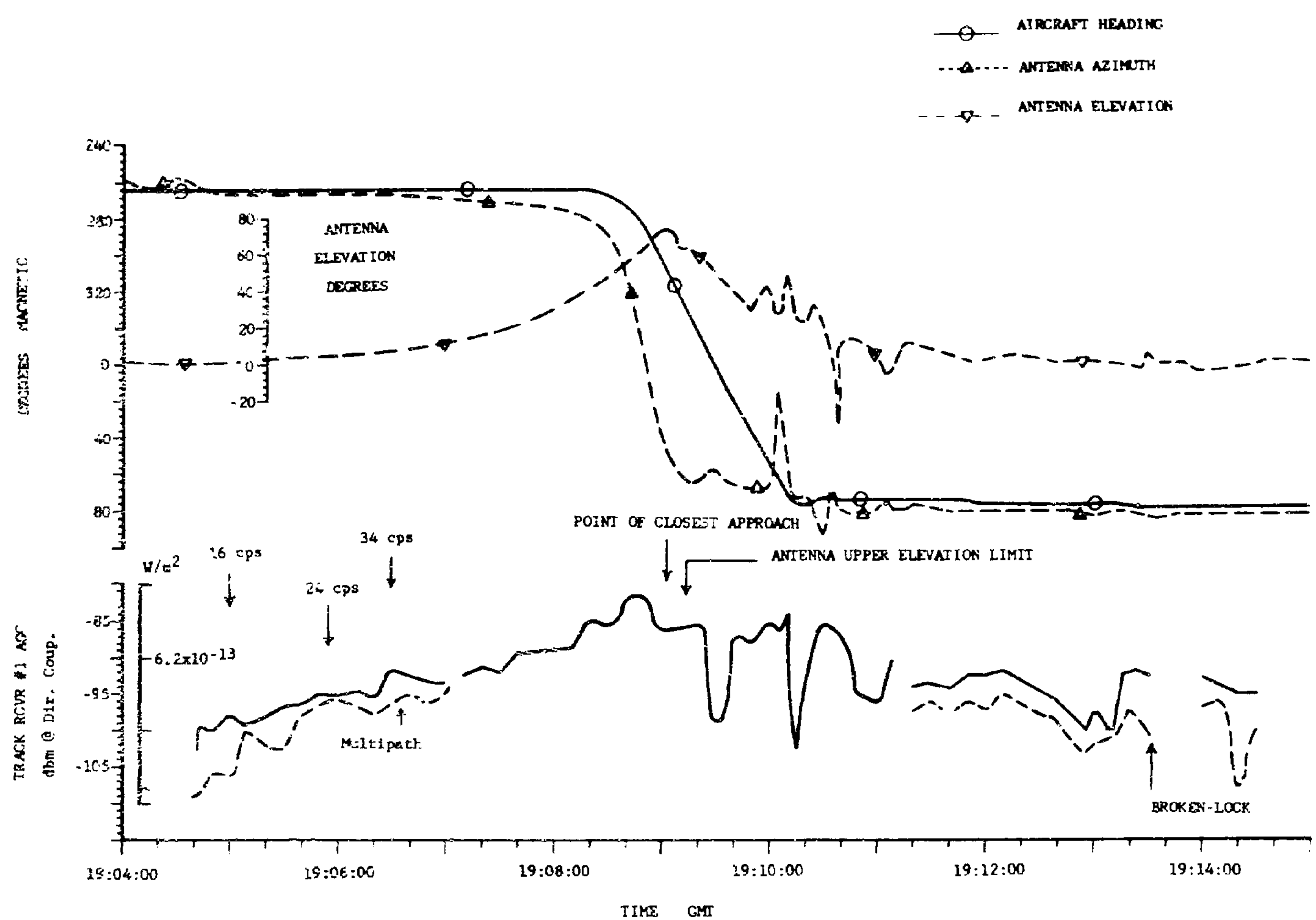


FIGURE III-5. SIGNAL LEVEL VS ANTENNA POINTING ANGLE FOR GEMINI ORBIT 44

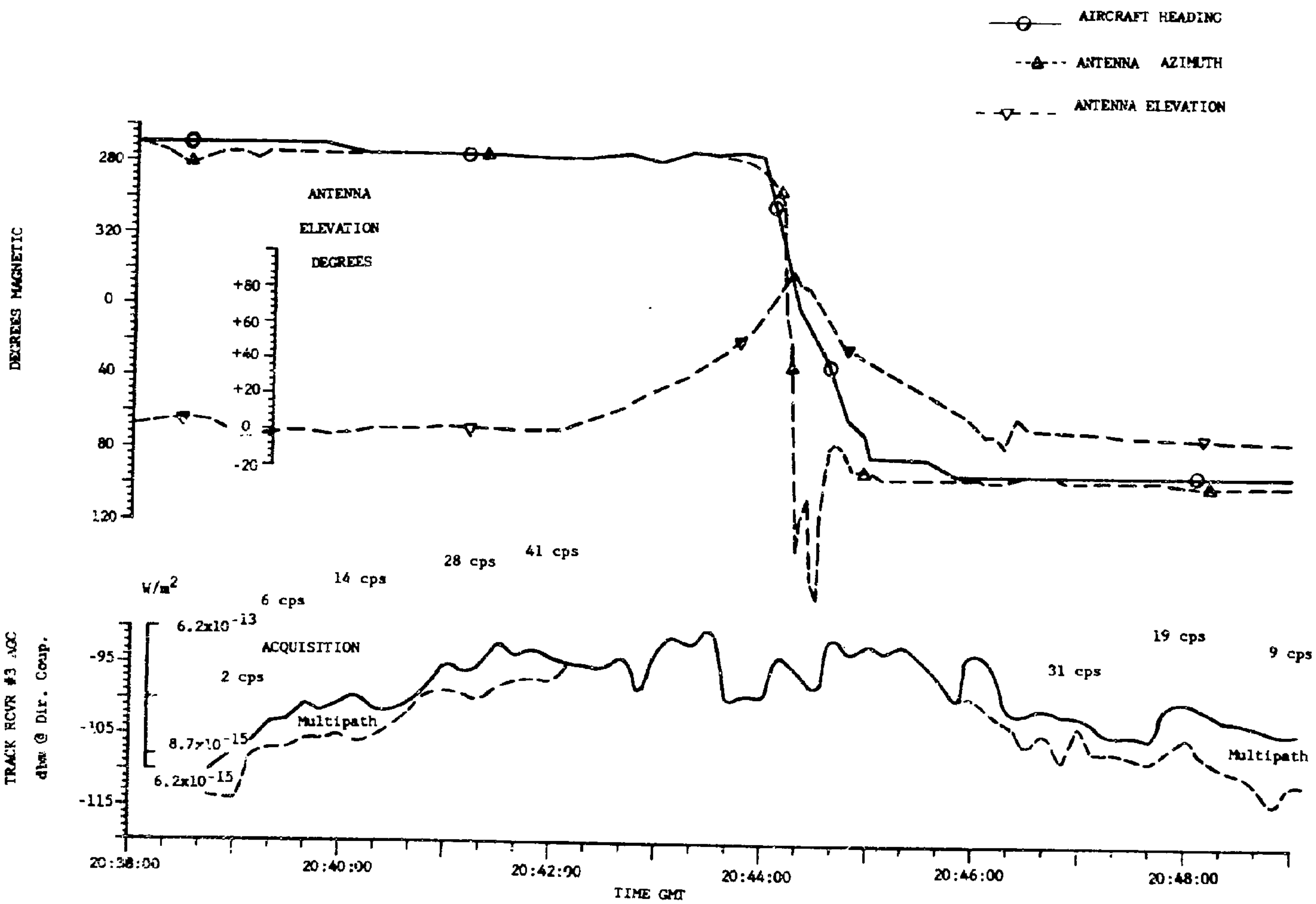


FIGURE III-6. SIGNAL LEVEL VS ANTENNA POINTING ANGLE FOR GEMINI ORBIT 45

APPENDIX IV

AEROSPACE GROUND EQUIPMENT

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SYMBOLS

The following are definitions of source codes established at Contractor/USAF AGE Selection meetings.

CODE	DEFINITION
P	Item selected for procurement.
Z	Item to be furnished by contractor from residual D/T&E assets.
PZ	Partial quantity to be furnished by contractor from residual D/T&E assets. Balance of quantity selected for procurement.
M	Item to be locally manufactured or jury-rigged by AFETR or substitute item available at AFETR.
X1	Item to be furnished from Government inventory.

I. INTRODUCTION

The Aerospace Ground Equipment (AGE) evaluated during Category II testing was that required for aircraft and PMEE pre-mission checkout and maintenance. Where recommended AGE was not available, substitute items were utilized. The AGE used does not represent the total AGE required for support of the A/RIA aircraft, since many items recommended are utilized for depot level maintenance; such AGE could not be evaluated as it was not available.

II. SUMMARY

The objectives of the AGE evaluation were: (1) To verify that the recommended equipment does in fact perform the required tasks adequately, accurately, and reliably and (2) To determine its ease of operation. The evaluations were accomplished during the normal operations of the aircraft and subsystems. No special tests were scheduled to quantitatively evaluate AGE.

Much of the actual approved AGE was not available during Category II testing. In many cases Douglas and Bendix capital equipment was utilized. When equipment identical to approved AGE was not available, substitute equipment was used. A comparison of this equipment with approved AGE is delineated in Tables I, II, and III of this report.

III. TEST AND EVALUATION

The evaluation was conducted as a supporting objective during the Category II testing, as delineated in DAC Report 6171. The tests performed are specified in Bendix Radio Drawing 2078343.

Utilization of the AGE showed that it performed in a satisfactory manner within the time limitations established for preflight.

Evaluation of AGE manuals was not accomplished during the Category II Test Program due to their nonavailability. The manuals will be evaluated by the using agency during Category III Testing.

IV. RESULTS AND CONCLUSIONS

The AGE evaluation revealed no deficiencies in the equipment utilized during the Category II Test Program. Further evaluation of the approved AGE will be performed by the using agency during Category III Testing.

Evaluation of AGE during pre-mission checkout revealed that there were insufficient quantities of five items to support four major staging bases. The quantities were updated at the several Contractor/USAF AGE selection meetings.

V. RECOMMENDATIONS

Original recommendations of AGE were made in accordance with AFSCM/AFLCM 310-1 AFLC/AFSC, Form 9, Number S-4- -23. 0-3, as required by DD Form 1423, Data Item Number 074. AGE recommendations were progressively evaluated throughout the proposal and acquisition phases of the program with changes thereto and additions of AGE as analysis revealed a deficiency.

As a result of the AGE evaluation it is recommended that an ACE Model 405-2TMG air conditioning trailer be procured for A/RIA use. The specifications of this trailer were reviewed and it was determined that its capability and capacity can meet the PMEE and aircraft air conditioning requirements utilizing one unit in lieu of the planned three MA-3 units. The customer has been officially notified of the estimated unit cost and lead time required for procurement.

TABLE I

AGE USED FOR PREFLIGHT

Actual Equipment Utilized	Recommended AGE Item No.	Evaluation
Distortion Analyzer 330B - HP	AGERD #134 Distortion Analyzer 330B - HP Source Code M	Used during preflight of the Record Group in performing third harmonic distortion tests on the direct record channels. The 330B performs this task in a sufficient and satisfactory manner.
True RMS Voltmeter 320/A - Ballantine	AGERD #167 RMS Voltmeter 3400A - HP Source Code XI	Utilized satisfactorily in making voltage level measurements in the RF Group and on the wideband recorder. A comparison of the specification for the 320A and 3400A reveals that the units are nearly equivalent, with the 3400A having a greater accuracy.
Differential Voltmeter 883A - Fluke	AGERD #168 AC-DC Differential Voltmeter 741A - HP, Source Code M	The HF and Record Group operators used the 883A both in performing preflight and troubleshooting and concur with the validity of the recommendation for this item of AGE. The 741A is nearly equivalent to the 883A and an analysis of the measurements and accuracies to be made reveal that the 741A can perform the task.
VTVM 400D Hewlett-Packard	AGERD #31 VTVM 400H Hewlett-Packard Source Code XI	Utilized in determining things such as signal to noise ratios, frequency response, alignments, etc. The 400H is an adaptation of the 400D with meterface calibration and greater accuracy on the lower end of the frequency.

Actual Equipment Utilized	Recommend d AGE Item No.	Evaluation
VTVM 410C Hewlett-Packard	AGERD #130 VTVM 410C Hewlett-Packard Source Code XI	Used to perform preflight on the HF Group. Continued usage during category II testing reveals the meter is a compatible unit for the tasks required.
*Power Meter 431C Hewlett-Packard	AGERD #160 Power Meter 431B Hewlett-Packard Source Code XI	Used to check output power of the UHF/VHF signal generator during preflight; also utilized during maintenance activity. Operators found this item to be acceptable and compatible with the requirements involved. The 431B is an earlier version of the 431C and determined to be capable of performing the tasks required of the 431C.
Thermistor Mount 478 Hewlett-Packard	AGERD #156 Thermistor Mount 478 Hewlett-Packard Source Code XI	Used satisfactorily in conjunction with the above Power Meter.
Signal Generator 202J Boonton	AGERD #200 Signal Generator 202J Boonton Source Code XI	Utilized in setting up the RF Group, antenna gains, receiver calibration, output meter calibration and (S+N)/N curve, etc. and has performed such tasks quite adequately.
*Counter 5245L Hewlett-Packard	AGERD #139 Counter 1037B Systron-Donner Source Code M	Used by the HF and record group operators during preflight and to perform maintenance tasks. Observation of usage during Category II testing reveals that this counter was a very suitable piece of equipment. The Systron-Donner counter is equivalent to the 5245L.

Actual Equipment Utilized	Recommended AGE Item No.	Evaluation
Power Supply 6202B Harrison	AGERD #138 Technipower L-40.0-25.0M Source Code M	Utilized to set up proper deviation of the FM modulators and the data multiplexer. The voltage and current characteristics of the 6202B are compatible with the requirements and it handles the tasks adequately. A power supply having the appropriate voltage and current characteristics may be substituted for the 6202B.
Signal Generator 8614A Hewlett-Packard	AGERD #142 Signal Generator 8614B H-P Source Code P	Used to perform system sensitivity checks in the RF Group. The generator performed this task adequately. The 8614B will perform the same tasks just as well when used in conjunction with AGERD #160, Power Meter.
Degausser DG-2 Magnusonics	AGERD #149 Degausser D1250 Magnusonics Source Code P	Used to degauss magnetic tapes. It performed in the required manner. The D1250 is equivalent to DG-2.
*Volt OHM Meter 610 Triplett PSM-6	AGERD #6 PSM 6 Source Code XI	Used in many applications during preflight and in unscheduled maintenance. The PSM-6 is a very useful and capable meter for its intended use.
Wave Analyzer 310A Hewlett-Packard	AGERD #148 Wave Analyzer 310A H-P Source Code XI	Utilized satisfactorily in performing preflight of the wide band recorders.
Oscillator 651A Hewlett-Packard	AGERD #147 Oscillator 651A Hewlett-Packard Source Code P	Used on several tests in setting up the wideband recorder during preflight.

Actual Equipment Utilized	Recommended AGE Item No.	Evaluation
VHF Test Antenna P-0608 TACO	Part of AGERD #279 Mobile Test Set Eclipse-Pioneer Source Code M	Utilized in performing receiver sensitivity, range loss, receiver calibration and tracking receiver phasing adjustments.
UHF Test Antenna Scientific Atlanta 22-4	Part of AGERD #279 Mobile Test Set Eclipse-Pioneer Source Code M	Utilized in performing receiver sensitivity, range loss, receiver calibration and tracking receiver phasing adjustment.
Adapter UG-201/U	AGERD #312 Adapter UG-201/U Gremar Mfg. Co. Source Code P	Used to connect test equipment to PMEE equipment during preflight. The adapter properly interfaces the equipment and any equivalent adapter may be utilized.
Tee Adapter UG-274/U	AGERD #315 Tee Adapter UG-274 B/U Gremar Mfg. Source Code P	Used to connect test equipment to PMEE equipment during preflight. The adapter properly interfaces the equipment and any equivalent adapter may be utilized.
Adapter UG-349A/U	AGERD #316 Adapter UG-349A/U Gremar Mfg. Source Code P	Used to connect test equipment to PMEE equipment during preflight. The adapter properly interfaces the equipment and any equivalent adapter may be utilized.
*Oscillator 200CD H-P	AGERD #135 Oscillator 200CD Hewlett-Packard Item Cancelled	Utilized throughout preflight also for operational maintenance. The 200CD satisfied the requirements for an audio oscillator. AGERD #135 was cancelled at AGE Selection Meeting #2 on 5-16-66 as it was determined that AGERD #147 has the capability of performing the same tasks and thus one piece of equipment is eliminated.

TABLE II

AGE USED FOR UNSCHEDULED MAINTENANCE

The below listed items of AGE were utilized during Category II Testing as maintenance items. This equipment was used as required for unscheduled maintenance in support of preflight. These items of AGE have performed the tasks required of them in an efficient and timely manner with no recommendation for better or different equipment. (See also items preceded by an asterisk in the preceding Table I.)

Actual Equipment Utilized	Recommended AGE Item No.	Remarks
Sweep Generator 605 Alfred	AGERD #194 Sweep Generator 631D-51 Alfred Elec. Source Code P	The RF Group operators used the 605 in aligning the parametric amplifier. The recommended 631D-51 will perform this function quite readily.
Noise Meter 342A Hewlett-Packard	AGERD #193 Noise Meter 342A Hewlett-Packard Source Code XI	Utilized in measuring system noise temperatures and alignment of the parametric amplifier.
VHF Noise Source 343A H-P	AGERD #197 VHF Noise Source 343A H-P Source Code XI	Used in conjunction with the 342A meter in measuring noise temperature and alignment of the VHF multicoupler.
UHF Noise Source 349A H-P	AGERD #192 UHF Noise Source 349A H-P Source Code XI	Used in conjunction with the 342A meter in measuring noise temperature and alignment of the parametric amplifier.
Crystal Detector 420A H-P	AGERD #7 Crystal Detector 420A H-P Source Code XI	Utilized in performing alignment of the parametric amplifiers.
Oscilloscope 453 Tektronic	AGERD #8 Oscilloscope 453 Tektronic Source Code P	Used in aligning the parametric amplifiers.

Actual Equipment Utilized	Recommended AGE Item No.	Remarks
Spectrum Analyzer SPA-4A Singer	AGERD #151 & 152 Spectrum Analyzer 8551B/851B H-P Source Code P	Used in checking out the UHF uplink transmitter. The 8551B/851B and SPA-4A are nearly equivalent items.
Test Set 979X-1 Collins Radio	Part of AGERD #389 Test Set Collins Radio Source Code P	Used to perform maintenance on RF and IF translators, together as a complete receiver or separately as an exciter or receiver. The test set may be used when required to perform adjustments and isolate faults down to the module or circuit card level.
Tracking Receiver Test Set CP100139 Bendix Radio	AGERD #307 Tracking Receiver Test Set CP100139 Bendix Radio Source Code P	Utilized in service and alignment or the tracking receivers.
Voice & Telemetry Test Set CP100140 Bendix Radio	AGERD #308 Voice & Telemetry Test Set CP100140 Source Code P	Utilized in service and alignment of the voice/telemetry receivers.
Attenuator 50-20 Weinschel	AGERD #233 Attenuator 10-20 Weinschel Engr. Source Code XI	Used in performing RF input tests. The major difference between the 50-20 and the 10-20 is the frequency range. The frequency range of the 50-20 is 0-3.0 GC and the range of the 10-20 is 0-1.5 GC which is sufficient to cover the requirement.
Attenuator 50-10 Weinschel	AGERD #130 Attenuator 50-10 Weinschel Engr. Source Code XI	Utilized in performing routine service and alignment on the parametric amplifiers.
Attenuator 50-6 Weinschel Engr.	AGERD #181 Attenuator 50-6 Weinschel Engr. Source Code XI	Utilized in performing routine service and alignment on the parametric amplifiers.

Actual Equipment Utilized	Recommended AGE Item No.	Remarks
Attenuator 50-3 Weinschel Engr.	AGERD #188 Attenuator 50-3 Weinschel Engr. Source Code XI	Utilized in performing routine service and alignment on the parametric amplifiers and service and alignment of the UHF multicoupler.
Frequency Converter 5253B Hewlett-Packard	AGERD #140 Counter Extender Plug-In 1291 Systron-Donner Source Code M	Used to service and align the antenna mount assembly. Both of these converters extend the frequency range of the basic counter (5245L and AGERD #139) to 500 MHz.
Termination 535MN Weinschel Engr.	AGERD #144 Termination 535MN Weinschel Engr. Source Code P	Used in performing maintenance on the data dump transmitter. It also can be utilized in servicing and alignment of the antenna mount assembly.
Frequency Meter 536A H-P	AGERD #298 Frequency Me[illegible] 536A H-P Source Code X[illegible]	Used in aligning and testing of the parametric amplifiers.
Attenuator 355DL Hewlett-Packard	AGERD #335 Attenuator 355D Hewlett-Packard Source Code XI	Utilized in performing alignment on the parametric amplifiers.

AGE TO SUPPORT AIRCRAFT, [illegible]

Actual AGE Utilized	AGE Recommended	Remarks
Towbar (tooling type) D652-5-71799 HF1 Douglas Aircraft and Towbar (production) J100034-51 Douglas Aircraft	AGERD #1 Towbar J100034-501 Douglas Aircraft Source Code PZ	Both the tooling type towbar and the production type towbar were used during the flight test program and proven to be compatible with the aircraft and tug interfaces. The production towbar was also broken down into sections, loaded and transported on board and removed from the A/RIA to verify ease of installing in and removing from A/RIA.
Ground Air Conditioner Adapter F71195 Boeing Co.	AGERD #278 Ground Cooling Air Adapter J100126-1 Douglas Aircraft Source Code P	The F71195 was used when air conditioning was required until the J100126 became available. The J100126 eliminated the undesirable moment on the aircraft fitting and reduced the high pressure loss encountered by the F71195.
Kit Adapter 958C543-2 Westinghouse	AGERD #276 Kit Adapter 958C543-2 Westinghouse Source Code PZ	No problems were encountered interfacing the aircraft AC wiring to the AC power system tester and performing AC power system tests.
High Pressure Oxygen Fitting Adapter D263-A101567-PTE1 Douglas Aircraft	AGERD #393 Oxygen Servicing Trailer Adapter J100134-1 Douglas Aircraft Source Code P	The PTE1 was used to service the GOX system as required during Category II testing. The J100134-1 was not available during Category II, but the components and tubing structure of the J100134-1 are similar to the PTE1.

Actual AGE Utilized	AGE Recommended	Remarks
Radome Installation & Removal Fixture J100129-1 Douglas Aircraft	AGERD #351 Radome Installation & Removal Fixture J100129-1 Douglas Aircraft Source Code P	A test was conducted to verify the fixture's compatibility and performance. The fixture was interfaced with an engine lift trailer and the radome sling and used to remove and install a radome on an A/RIA. Minor problems were encountered and resolved immediately by Engineering.
Radome Sling D-652-J100225-HFH1 Douglas Aircraft	AGERD #394 D-652-J100225-501HFH1 Douglas Aircraft Source Code P	AGERD #394 is a modification of D-652-J100225-HFH1 and was associated with the test of the radome installation and removal fixture. No problems were encountered with this item; the recommendation is deemed as valid.
AGERD #326 Yoke & Pedestal Sling Set A100141-1 Eclipse-Pioneer	AGERD #326 Yoke & Pedestal Sling Set A100141-1 Eclipse-Pioneer Source Code PZ	The sling set has been used throughout Category II Testing and A/RIA production. Minor modifications were required and the sling set now performs the required tasks in a satisfactory manner.
AGERD #346 Reflector Sling SK90240 Bendix Radio	AGERD #346 Reflector Sling SK90240 Bendix Radio Source Code Z	The sling set has been used throughout Category II testing and A/RIA production. Minor modifications were required and the sling set now performs the required tasks in a satisfactory manner.
AGERD #326 and #346	AGERD #352 Antenna Assy Handling Fixture J100130-1 Douglas Aircraft Source Code P	A test was conducted to verify the fixture's compatibility and performance. The fixture was interfaced with the radome installation and removal fixture and used to remove and install the antenna assembly on the A/RIA. Minor problems were encountered and resolved immediately by Engineering.

Actual AGE Utilized	AGE Recommended	Remarks
MA-3A Air Conditioning Cart	MA-3 Air Conditioning Trailer	The air conditioning cart has not been completely evaluated (at high ambient temperatures) due to the season of the year in which Category II testing was conducted. The cart has performed in a satisfactory manner to the present time.
Gremco 8H AC/DC Ground Power Unit and B10B Electrical Power Cart	MD3A Electrical Power Cart	The Gremco electrical power cart was in use throughout Category II testing. The B10B power cart was also used several times. It is almost identical to the MD3A cart. Both carts performed in a satisfactory manner.

APPENDIX V

ELECTRO-INTERFERENCE

TEST REPORT

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LIST OF ABBREVIATIONS

ALOTS	Airborne Lightweight Optics Tracking System
A/RIA	Apollo/Range Instrumented Aircraft
EMC	Electromagnetic Compatibility
ICT	Interference Compliance Test
PMEE	Prime Mission Electronic Equipment
TWA	Trailing Wire Antenna
UHF	Ultra High Frequency
VHF	Very High Frequency
WPA	Wing Probe Antenna

SECTION I

INTRODUCTION

This document presents a partial evaluation of the Electromagnetic Compatibility (EMC) Tests on the Apollo/Range Instrumented Aircraft (A/RIA). The complete Electro-Interference Test Report, DAC 56222, which satisfies A/RIA data item requirement (AFSCM 310-1), Number T-22-56.0, is submitted as a part of the Category I Final Test Report.

The tests were conducted in accordance with the applicable portion of the customer-approved test procedures, A/RIA Drawing A100284. The applicable portions of the A100284 contains the "Interference Compliance Test" (ICT) procedures which were prepared in compliance with the requirements of MIL-E-6051C.

SECTION II

SUMMARY

The Electromagnetic Compatibility test program for the Apollo/Range Instrumented Aircraft (A/RIA) was completed on the aircraft numbers 1 (60-372), 2 (60-375), and 4 (61-327) during the period of October 24, 1966 through June 1967.

The testing program objectives were accomplished and summarized in three general areas as follows:

a. Results of the tests demonstrated that the A/RIA system is free of any catastrophic incompatibilities.

b. The tests defined the subsystem limitations and restrictions that must be tolerated to achieve mission success.

c. The tests demonstrated the system compliance with the contractor's Interference Control and Test Plans as required by the general specification MIL-E-6051C.

The tests were performed in compliance with the conditions specified in the TU-28327 test plan and the A100284 detailed test procedures.

The audio interference test results demonstrated that the system intercommunication subsystems comply with MIL-E-6051C specifications for "unacceptable responses" except certain existing conditions that were evaluated and dispositioned upon receipt of the aircraft.

Results of the PMEE and the Aircraft Subsystem Susceptibility tests demonstrated the compatibility of the subsystems in the environment and defined the necessary characteristics to permit management of the frequency spectrum for a prescribed mission.

SECTION III

TEST AND EVALUATION

3.1 PURPOSE OF THE TEST

The purpose of the Electro-Interference Test reported in this document is to assure electromagnetic compatibility of the electrical/electronic subsystems within the A/RIA system by identifying interactions for evaluation and to demonstrate the functional electromagnetic compatibility of the A/RIA system to the requirements of MIL-E-6051C.

3.2 TEST SPECIMEN

The test specimen consisted of the A/RIA system as listed in Table I. The first, second, and fourth aircraft system were subjected to portions of the ICT as described and on the dates shown. The aircraft were completely equipped with all the electrical/electronic equipment installed in the normal configuration except as documented in DAC 56148. The exceptions that were necessary to accommodate the required instrumentation and monitor system performance in accordance with the test procedure are documented by Report DAC 56148, Exhibit to DAC 56222.

A/RIA System No. 2 was selected as the A/RIA EMC test specimen for the formal ground Interference Compliance Test because No. 1 system was fully instrumented for the Category II test program. The instrumentation aboard No. 1 aircraft consisted of a large quantity of equipments and associated wiring that rendered the system an unrealistic complex to acquire EMC data. The flight data were collected on system No. 1 and No. 4 after the instrumentation was removed and restored to production configuration.

A/RIA system No. 4 was utilized as the specimen for the compatibility test of the ALOTS modification and for the completion of the PMEE compatibility testing in the flight environment.

3.3 FLIGHT TESTS

Flight testing for electromagnetic compatibility consisted of testing specific interference conditions specified by the Category I Test Procedures, A100284. Specific tests accomplished in flight were selected based on ground test results and other combinations that could not be realistically evaluated by ground tests, such as interferences from HF transmissions, antenna isolations, etc. The results are reported by the Category I Test Report on Electromagnetic Compatibility, DAC-56148.

Evaluation of ground EMC test results developed the specific tests to be performed in flight. The testing areas which were evaluated in flight were responses of the HF receivers, VHF telemetry track and voice receivers, L-Band telemetry receivers, and UHF telemetry and track receivers, due to the following antenna conducted signals:

a. Co-channel transmitter

b. Adjacent channel transmitters

c. Transmitter harmonics

d. Receiver spurious

e. Intermodulation products

Flight evaluation of the above tests generally revealed that the majority of ground detected VHF, L and UHF interference conditions, due to antenna isolations, did not exist in the flight environment. Identification of all the actual receiver responses was evaluated and dispositioned by restricting usage of equipments which have secondary importance to accomplishing the mission. Specific restrictions are included in the "Recommendation" section of the Category I Electromagnetic Compatibility test report, DAC-56148.

Interference, due to HF transmissions, was generally more severe in the flight environment than during ground testing, due to the airframe effects at the HF frequencies. Operational restriction for HF equipments, based on the test results, includes adjacent channel separation, transmitter harmonics and second and third order intermodulation.

The only incompatibility detected in the A/RIA system of a nature requiring corrective action was the effect on the tracking antenna servo circuit by HF transmissions which appears to be more severe when using the TWA. The deficiency was detected during flight testing and has been repeated by ground simulations. This problem was corrected by the incorporation of ECP 0071, which added a special RF filter to the Antenna Control circuitry, OA-11. The adequacy of the design change was verified by flight test on aircraft 61-330 on 9 August 1967.

The A/RIA-ALOTS Electromagnetic Compatibility evaluation revealed no incompatibilities during ground testing except as follows:

a. The ALOTS subsystem contains an intra-equipment self-compatibility deficiency which existed before installation into the A/RIA complex. The photo camera drive motor degrades the ALOTS video and tracking servo system by producing spurious track points within the video tracking system.

b. HF transmissions on any HF antenna cause heavy modulation of the ALOTS video; they also cause the servo system to jitter and lose track. The deficiency occurred for HF transmission below 14 MHz only.

Flight testing of the A/RIA-ALOTS system confirmed the ALOTS susceptibility to HF transmissions between 2 and 11 MHz. ALOTS performance became marginal when HF transmissions were between 11 and 14 MHz but was satisfactory for all frequencies above 14 MHz. Both system deficiencies discussed above are peculiar to the ALOTS subsystem only and improvements to correct the discrepancies are not within the scope of this program.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

The basic goal of the A/RIA electromagnetic compatibility program, to control the design of the A/RIA system so that it is capable of performing its prescribed mission free of disabling electromagnetic interferences, has been achieved by employing certain subsystem restrictions specified in this section.

The system compatibility tests, performed in accordance with existing procedures and the results reported by DAC-56148, have defined the necessary characteristics of the subsystems and system to permit mission planning and a continuing compatibility evaluation into the operational phase (Category III) of the program. The contractor considers the compatibility evaluation of any system to be a continuing program and is necessary to achieve a higher degree of mission success. It must be recognized that, no matter how thorough the interference and compatibility test planning, it is highly probable that minor additional electrical interferences, not reported herein, will be detected after the delivery of the system to the using agency.

Results of the comprehensive electro interference tests have:

a. demonstrated that the A/RIA system is free of any catastrophic incompatibilities,

b. defined the subsystem limitations and restrictions that must be tolerated to achieve mission success, and

c. demonstrated the system compliance to the contractor's Interference Control and Test Plans as required by the general specification MIL-E-6051C.

4.2 AUDIO INTERFERENCE

The audio interference test results show that the newly designed intercommunication subsystem fully complies with the requirements of MIL-E-6051C. The existing AIC-18 intercommunication subsystem exceeds the specification requirement for unacceptable aural output power of 1.125 microwatts. The response is considered an undesirable response that does not degrade the system capability or cause nuisance or irritating effects on the operators. The condition is considered satisfactory based on the following:

a. Prior service of the aircraft

b. Levels are controllable by the operators

c. The condition was existing before the A/RIA modification began, and is documented by DAC-56108 report. An early evaluation of the condition determined that rework was not warranted.

The Public Address Subsystem (AIC-13) responses due to spotlight intensity control and beacon light operation are not recognizable in the mission environment, as demonstrated by the Category II Flight Tests. The response is considered undesirable but does not degrade system performance or exceed specification limits.

4.3 PMEE SUBSYSTEMS

The susceptibility of the Voice and Telemetry data receivers to on-board transmitter sources must be tolerated by proper frequency usage and management of the spectrum for each mission. Specific restriction for equipments and subsystems are included in Table II of this report.

The susceptibility of the tracking servo circuit to HF transmission was not detected during the performance of the electro-interference ground testing. Subsequent HF transmission testing in the flight environment caused random responses in the antenna servo system. This problem was corrected by the incorporation of ECP 0071, which added a special RF filter to the antenna control circuitry, OA-11. Details of the problem and design fix are documented in EMI Report DAC 56148.

4.4 AIRCRAFT SUBSYSTEMS

The susceptibility of communication receivers to newly installed transmitter sources must be tolerated by proper frequency usage and management of the spectrum for each mission. Specific restrictions for equipments and subsystems are included in Table II of this report.

4.5 RECOMMENDATIONS

It is recommended that Table II, "Equipment Operational Restrictions," be utilized to assist in mission planning.

It is recommended that the electromagnetic compatibility evaluation of the system be continued in the operational phase (Category III) of the program.

Table II should be used as a guide to direct the evaluation and should be revised as test results dictate. It is feasible that some restrictions now listed on the table can be relaxed over parts of frequency bands for the same mode of interference.

TABLE I

EMC TESTING FOR A/RIA

Test Specimen (Aircraft Serial Number)	A/RIA Unit No.	Date of Test	Type of Test	Test Procedure
60-372	1	10-24-66 through 10-25-66	Milestone EMC	A100284 paras. 4.2.4, 4.2.5, and 4.2.6 as specified by SEO 002A
60-375	2	1-19-67	PMEE/Aircraft EMC	A100284 paras. 4.2.1 through 4.2.6
60-372	1	3-14-67	PMEE/Aircraft EMC-Flight	A100284, Para. 4.2.7
61-327	4	2-25-67	ALOTS EMC	A100284 paras. 4.2.8 and 4.2.9
61-327	4	5-25-67	ALOTS EMC-Flight PMEE/Aircraft EMC Flight	DAC 56171 Supplement #1 A100284 para. 4.2.7

TABLE II

EQUIPMENT RESTRICTIONS TO ACHIEVE
A/RIA AND A/ARIA-ALOTS SYSTEM COMPATIBILITY

	EQUIPMENT REQUIRED FOR MISSION	RESTRICTED USAGE OF EQUIPMENT	TYPE OF RESTRICTION
1.	VHF Telemetry and Tracking Receivers	(a) AN/ARC-34 Transmissions	Cochannel frequency band 225-260 MHz
		(b) 17L-7A Transmissions	First sub-harmonic of the receiver frequencies or band 116-130 MHz
		(c) AN/ARC-34 (F_1) and HF Transmission (F_2) simultaneously	(F_1-F_2, F_1+F_2), (F_1-2F_2)
2.	VHF Voice Receiver	(a) AN/ARC-34 Transmission	Cochannel frequency 296.8 MHz
		(b) 17L-7A Transmissions	First sub-harmonic frequency 148.4 MHz
		(c) AN/ARC-34 (F_1) and HF Transmission (F_2) simultaneously	(F_1-F_2, F_1+F_2), (F_1-2F_2)
3.	VHF Data Dump Transmitter	(a) AN/ARC-34 Receiver	Cochannel frequency
4.	HF Receivers	(a) HF Transmission	Adjacent channel less than 10% separation
		(b) HF Transmission	First sub-harmonic of the receiver frequency
	AF Receivers WPA	(c) Two HF Transmissions (F_1 and F_2) simultaneously on TWA and WPA	(F_1+F_2, $2F_1+F_2$, $2F_1-F_2$)
5.	ALOTS	(a) HF Transmissions	All frequencies between 2 - 13 MHz on all HF antennas
6.	UHF/VHF Tracking Antenna Servo System	(a) HF Transmissions on TWA before incorporation of ECP 0071	All frequencies

REFERENCES

MIL-E-6051C, System Compatibility and Interference Control Requirements, Aeronautical Weapon System

MIL-I-6181D, Interference Control Requirements, Aircraft Equipment

A100284, Electro-Interference Test Procedures

A100206, Interference Control Specification

A100207, Bonding Control Specification

A100208, Cabling and Wire Class Specification

TU-28339, Aircraft Receiving Test A/RIA Unit #1

DAC-56108, Aircraft Receiving Test A/RIA Unit #2

DAC-56133, Aircraft Receiving Test A/RIA Unit #3

DAC-56111, Electrical Bonding Test Procedure

MIL-B-5087B, Bonding, Electrical

MIL-STD-831, Test Reports, Preparation of

2078571, PMEE RFI/EMI Test Report

TU-28327, Category I Test Plan

DAC-56171, Category II Test Plan

DAC-56148, Electromagnetic Compatibility Test Report

DAC-56222, A/RIA Electro-Interference Test Report

APPENDIX VI

RELIABILITY/MAINTAINABILITY

FOREWORD

This report is submitted under Air Force Contract AF 19(628)-4888, DD Form 1423, TSAF R-3-15.0-1. Significant processes and products of the A/RIA Reliability/Maintainability demonstration and verification are documented for the period of 28 October 1966 through 14 March 1967.

ABSTRACT

The Reliability and Maintainability Tests, demonstrations, and system analyses were conducted in accordance with the plan outlined in Douglas Report No. 52928. Status and failure reports and similar basic records, logs, and forms were used to collect the system operation and R/M data.

The Douglas Reliability/Maintainability Engineering Group collected all the R/M data on the aircraft and PMEE subsystems as outlined in Annex B, Vol. II of Douglas Report 56171. These data were obtained from the PMEE operating engineers engaged in the Category II flight tests. From these sources, the group completed the evaluation of the reliability and maintainability of the complete A/RIA System.

Test data for the A/RIA R/M Program was derived from Douglas Failure and Rejection Reports (FARR), Aircraft Records, Category II PMEE Failure Report and the PMEE Log Book. The PMEE Log Book is a documentary history of all the components of the PMEE System installed in the A/RIA Aircraft. The Log Book is maintained by the operating personnel and provides the following data:

a. A permanent record of performance.

b. Historical documentation of aircraft serial number, PMEE system number, component equipment numbers, modifications installed, equipment failures, and maintenance accomplished.

The above course of action resulted in the following:

a. The A/RIA System Reliability demonstration was begun 28 October 1966, and completed 21 January 1967, after 113 hours of flight testing.

b. Analysis of the Aircraft Modification Subsystems was begun 28 October 1966, and completed 14 March 1967. Analysis of the Aircraft Modification Subsystem yielded an MTTR of 0.980 hours measured against a requirement of 1.36 hours.

From these results, it is concluded that the A/RIA System meets the design requirements in both reliability and maintainability.

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LIST OF ABBREVIATIONS, SYMBOLS, AND DEFINITIONS

$\underline{R}$	Symbol for Reliability
$\underline{M}$	Symbol for Maintainability
MTTR	Mean Time To Repair
MTBF	Mean Time Between Failures
λ	Failure Rate
α	Producers Risk (Douglas)
β	Consumers Risk (Air Force)
θ_1/θ_0	Discrimination Ratio - The ratio of the specified MTBF (θ_1) to the minimum acceptable MTBF (θ_0).
Reliability	The probability that material will perform its intended function for a specified period under stated conditions.
Maintainability	Maintainability is a characteristic of design and installation which is expressed as the probability that an item will conform to specified conditions within a given period of time when maintenance action is performed in accordance with prescribed procedures and resources.
Truncation	The minimum test time to satisfy the customer and contractor risks and maximum number of failures allowed, without reaching an accept or rejection decision.

SECTION I

INTRODUCTION

1.1 PURPOSE

The objective of the Reliability/Maintainability Program was to attain the highest A/RIA System Reliability with minimum maintainability time, to ensure maximum system availability at minimum cost.

1.2 SCOPE

The Reliability/Maintainability Plan was designed to provide continuous support and guidance to the development of the A/RIA System. This was accomplished initially at the design level by ensuring that reliability and maintainability concepts were essential ingredients of every design. Reliability and maintainability personnel were assigned to work directly with the designer and provide him with R/M guidelines, inputs for trade-off studies, R/M analysis, and to assist in component and equipment selection. Reliability and maintainability also functioned in the evaluation of all preliminary, interim and final designs, including those generated by subcontractors and suppliers, to determine the attainment of R/M goals. Through tests and demonstrations of the equipment, subsystems and the system proper, R/M verified that the requirements of the A/RIA system were met.

The plan was structured to enhance the Reliability/Maintainability support inherent in the AFSCM 375-5 System Engineering Management Procedures.

SECTION II

SUMMARY

2.1 OBJECTIVES

The R/M objective for the Category II Test Program was to demonstrate and verify system hardware performance in as near an operational environment as possible. A sample size of three (3) was selected because of the production availability of the first three aircraft during Category II Testing.

2.2 RELIABILITY

Category II Reliability demonstration testing commenced with the first flight of Aircraft No. 1, 28 October 1966, with a full complement of PMEE on board. The test was based on a sequential test plan, outlined in Report No. 52928 and in accordance with ESD-TDR-64-616 Reliability/Maintainability Handbook. The significant parameters governing the accept/reject criteria are as follows:

MTBF = 50 hours

Truncation time = 310 hours

Maximum number of failures allowed = 10

Customer risk = 10%

Contractor risk = 10%

Discrimination Ratio = 0.438

The above parameters result in the following accept/reject equations. These equations put in chart form are as shown in Figure VI-1.

Accept Curve

$$F_A = 0.03226\,t - 2.6515$$

Reject Curve

$$F_R = t + 2.6515$$

From the time of the first flight, all flight hours accumulated by Aircraft Nos. 1, 2 and 3 with a full complement of operational PMEE on board were counted as test hours. Likewise from the same point in time, all valid failures were charged to the system. A valid failure was defined as a failure of any component of the subsystems that would result in a mission abort or significant degradation of mission capability. Failure data were derived from Failure and Rejection Reports, Test Failure Reports, and A/RIA PMEE Log Books.

Eight PMEE in-flight failures and one aircraft modification in-flight failure occurred during Category II flight operations. All of these failures were analyzed and scored as valid or invalid, based on the aforementioned definition of a valid failure (ref. Table II).

One valid failure occurred after 8.3 hours of testing. This failure was analyzed, and a design change resulted.

All other in-flight failures were scored as invalid based on the redundancy built into the system.

The A/RIA system reliability demonstration was completed 21 January 1967, after 113 hours of flight testing.

Since slippage in the Category I Reliability demonstration test schedule caused the Category I versus Category II sequence to essentially be reversed, all failure data occurring in Category II ground and flight operations were analyzed and used to define potential problem areas in the Category I Reliability demonstration.

2.3 MAINTAINABILITY

The demonstration of A/RIA system MTTR does not fall exclusively under Category I or C tegory II. Hence, some data for PMEE MTTR was accumulated during Ca gory II testing. All data to demonstrate the MTTR of the Aircraft Modification Subsystem was accumulated during Category II testing on an as-failed basis. The reason for demonstrating the MTTR of the Aircraft Modification Subsystem on an as-failed basis was because of the philosophy agreed upon that no failures will be induced into equipment while installed in the aircraft.

Analysis of Aircraft Modification Maintainability Data yields a MTTR of 0.951 hours as measured against a requirement of 1.36 hours.

The MTTR demonstration for the PMEE was accomplished at Bendix under the Category I Test Program.

SECTION III

RELIABILITY ANALYSIS

3.1 SCOPE

The A/RIA System MTBF requirement is 50 hours. To demonstrate that this value has been achieved, this analysis includes the discrepancies, replacements, and realignments on prime mission electronic equipment (PMEE) and A/RIA aircraft modification subsystem equipment that occurred during flight. This analysis includes a discussion of information contained in failure reports, PMEE log books, inspection discrepancy reports (including Pilot's Flight Inspection Reports), records of removals and flight reports. In addition, whenever necessary, flight test personnel were interviewed in order to better analyze the data for scoring for the sequential test plan (Figure VI-1). Only failures that occurred during flight are included in this discussion.

Applicable Subsystems are as follows:

A. Aircraft Modification Subsystem -

1. Electrical Power
2. Interphone
3. PMEE Air Conditioning

B. PMEE Subsystems -

1. Timing
2. Voice and Telemetry
3. HF Communications
4. Master Control Console

3.2 ANALYSIS

There were a total of sixty-one (61) failure reports during the demonstration, nine (9) of which were Aircraft Subsystem and fifty-two (52) PMEE. Of the sixty-one (61) reports, nine (9) were in-flight failures; one of which was Aircraft Subsystem and eight (8) were PMEE. (Ref. Tables I and II.) There were fifty-two (52) ground failure reports, eight (8) of which were Aircraft Subsystem and forty-four (44) PMEE.

Ground failures did not enter into the scoring but were recorded for historical data. Ground failures were a result of regular ground tests, special tests, production acceptance tests, human error and others. One notable ground failure was the burned windings of the VHF/UHF Antenna Azimuth Drive Motor

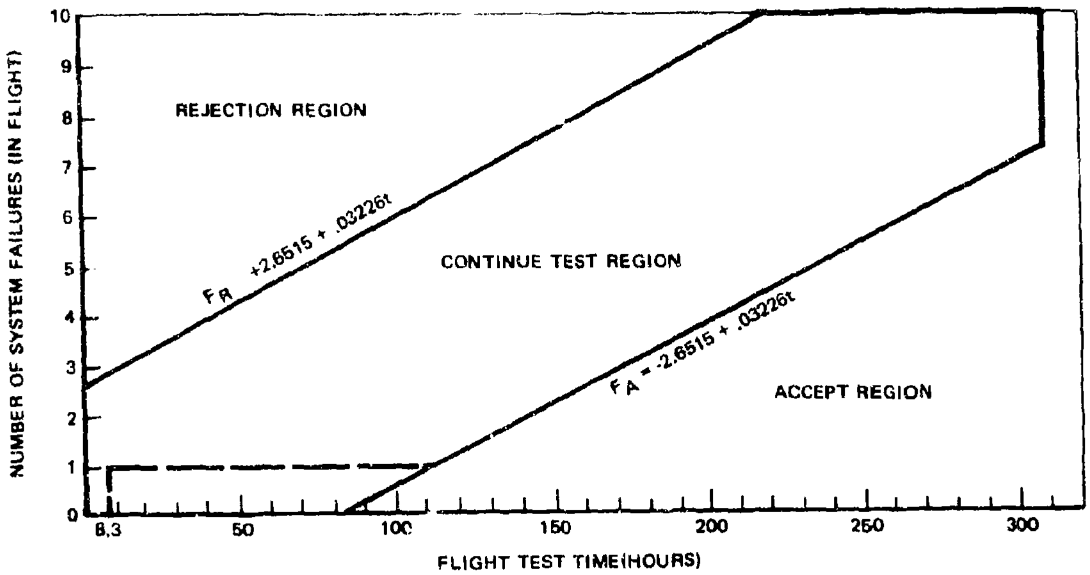

FIGURE VI-1. CATEGORY II RELIABILITY SEQUENTIAL TEST CHART

which occurred when the clutch seized on Aircraft No. 3. The azimuth drive system design was improved by the installation of dual drive motors, improved magnetic clutches and hardened drive gears.

Refer to Tables I and II for Aircraft Modification Subsystem and PMEE failure reports that occurred during the reliability demonstration.

During the flight test program, Pilot's Flight Inspection Reports were used to record in-flight "squawks" of the pilots and PMEE operators. These did not necessarily culminate in failure reports. For this reason, it was necessary to review these items in addition to the regular failure reports. They were reviewed and screened for applicability and written as a part of a discrepancy-discussion type of report.

Annex A is a flight-by-flight failure recap showing in-flight discrepancies and a discussion of each problem. Also included is a statement as to how they were scored. Ground failures are not included.

The extent of the data analysis was to evaluate each in-flight failure for its validity as a system failure. Judgments were made for scoring purposes by personnel familiar with reliability math models with technical assistance from PMEE Operators and Engineers.

Only one failure was adjudged to be valid and scored as a system failure. This was caused by the airflow interlock vane in the PMEE Cooling System becoming jammed, which resulted in a false indication of no airflow. This in turn shut off the power to two of the three HF receivers. A minimum of two receivers is required for mission performance.

The system failure occurred after eight (8) hours and twenty (20) minutes or eight and three-tenths (8.3) hours of flight test time. This was plotted on a sequential test chart (Figure 1). Testing was continued until enough flight hours were accumulated to reach the accept line of the chart. No further system failures occurred and the test was terminated after the decision value of one-hundred thirteen (113) hours was reached (Table III). A total of one-hundred sixteen (116) flight hours had been accumulated at the completion of the flight, 21 January 1967 (Table IV).

3.3 RESULTS

The accept decision value was reached with one valid system failure giving the customer a system equal to or better than a fifty (50) hour MTFB with a 90% confidence level.

SECTION IV

MAINTAINABILITY ANALYSIS

4.1 SCOPE

The demonstration of A/RIA System MTTR did not fall exclusively under either Category I or Category II, but was accomplished by evaluation of maintenance data accumulated during flight test operations and normal flight operations. The PMEE MTTR was demonstrated during Category I Tests conducted at Bendix Radio. The results of the PMEE tests are contained in the Category I Test Report.

Observers were assigned from the Reliability/Maintainability Group to gather the MTTR data. These observers were thoroughly familiar with the applicable forms and procedures, the design functions of the equipment under observation, relevant maintenance practices and maintainability principles, data and methodology.

Acquisition of the data was accomplished through monitoring by Reliability/Maintainability Group personnel during flight operations and related tests and demonstrations. The data included total time to perform corrective maintenance tasks.

4.2 ANALYSIS

Analysis of the MTTR data was performed on a cumulative basis. Whenever possible, the data were analyzed and combined with the previous data in increments of ten data points. Maintenance data action items were collected from the first three A/RIA aircraft during the period of 28 October 1966 through 14 March 1967. The applicable Aircraft Modification Subsystems are as follows:

1. PMEE Cooling
2. Electrical Power
3. Interphone
4. Oxygen
5. Trailing Wire Antenna

During the above time span, 63 data points were collected from the first three A/RIA aircraft covering a total of 35 flights and 194:35 flight hours. For the purpose of this evaluation, the Aircraft Modification Subsystems were considered as one system and the evaluation of the acheived MTTR was accomplished at the system level.

The predicted failure rates that are listed in Table VIII-2 of Douglas Report 56171, Section 8, were utilized to weigh the actual maintenance times. The table shows the data and method of weighing.

The Mean Time to Repair (MTTR) for the Aircraft Modification Subsystems listed in Table VIII-2 of Douglas Report 56171, Section 8, based on the data

accumulated is 0.951 hours. The required MTTR is 1.36 hours.

The radome was omitted from the calculation since it was not included in Table VIII-2 for computing the required MTTR. The MTTR with the radome included is 0.957 hour, which is within the required MTTR.

4.3 RESULTS

The final A/RIA Aircraft Modification Subsystem MTTR has been computed and reported herein. Since the final MTTR is less than the specified MTTR, the requirement is considered to have been satisfied.

TABLE I

AIRCRAFT MODIFICATION SUBSYSTEM FAILURES

Failure Report Number	Aircraft Number	Date	Component	Inflight	Ground	System Failure	
						Yes	No
D18902	1	11-22-66	Fan - Cooling PMEE	x			x
D18921	1	12-9-66	Generator Control Panel		x		x
					x		x
356420	1	12-9-66	Voltage Regulator		x		x
344809	1	12-1-66	Frequency & Load Controller		x		x
D18939	3	12-8-66	Interphone Control Box		x		x
D32233	1	10-30-66	Interphone Control Box		x		x
D32234	1	11-6-66	Interphone Control Box		x		x
D22696	1	11-11-66	Annunciator Panel		x		x
D19227	1	11-7-66	Edge Light Panels		x		x

TABLE II

PMEE FAILURES

Failure Report Number	Aircraft Number	Date	Component	Inflight	Ground	System Failure	
						Yes	No
5	1	10-31-66	Airflow Vane	x		x	
6	1	11-4-66	Time Signal Generator		x		x
7	1	11-4-66	Antenna Control Assembly		x		x
8	1	11-3-66	Track Receiver		x		x
11	1	11-10-66	VHF Modulator		x		x
12	1	11-10-66	IF Translator		x		x
13	1	11-14-66	Track Receiver	x			x
14	1	11-21-66	Time Signal Generator		x		x
15	1	11-22-66	HF Receiver	x			x
16	1	11-30-66	HF Power Amplifier		x		x
17	3	12-5-66	Track Receiver		x		x
18	3	11-30-66	Parametric Amplifier		x		x
19	3	11-30-66	Azimuth Drive – Clutch		x		x
20	3	11-30-66	Azimuth Drive Motor		x		x
21	3	12-4-66	Voice Transmitter Cont Panel		x		x
22	3	12-7-66	Audio Center		x		x
23	3	12-10-66	Audio Center		x		x
24	1	11-30-66	HF Power Amplifier	x			x
25	1	12-12-66	VHF Multicoupler		x		x

TABLE II (Continued)

Failure Report Number	Aircraft Number	Date	Component	Inflight	Ground	System Failure	
						Yes	No
26	1	12-13-66	Dual Trace Amplifier		x		x
27	1	12-14-66	Remote Time Display		x		x
28	3	12-16-66	Voice Transmitter Cont Panel		x		x
29	3	12-16-66	Tracking Combiner		x		x
30	3	12-16-66	HF Power Amplifier		x		x
31	1	12-15-66	Parametric Amplifier		x		x
32	1	12-9-66	RF Voltmeter		x		x
33	2	12-20-66	Tracking Combiner	x			x
34	2	12-20-66	Signal Data Demod	x			x
35	2	12-20-66	Bearing Indicator	x			x
36	2	12-22-66	Track Receiver		x		x
37	2	12-10-66	UHF Subcarrier Osc & Exc		x		x
38	2	12-22-66	UHF Subcarrier Osc & Exc		x		x
39	3	12-20-66	Voice Transmitter Cont Panel		x		x
40	3	12-28-66	Audio Center		x		x
41	3	12-28-66	Audio Patch Panel		x		x
42	1	12-16-66	Time Signal Generator		x		x

TABLE II (Continued)

Failure Report Number	Aircraft Number	Date	Component	Inflight	Ground	System Failure	
						Yes	No
43	1	12-21-66	Time Signal Generator		x		x
44	1	12-28-66	Time Signal Generator		x		x
45	1	12-29-66	Time Signal Generator		x		x
46	3	12-28-66	Parametric Amplifier		x		x
47	3	12-15-66	Audio Center		x		x
48	3	1-5-67	RF Translator		x		x
49	3	1-6-67	RF Translator		x		x
50	3	1-6-67	RF Translator		x		x
51	3	1-6-67	Azimuth Mechanism — Stow		x		x
52	1	1-10-67	RF Tuner		x		x
58	1	1-7-67	RF Translator	x			x
59	1	1-10-67	Doppler Oscillator		x		x
60	1	1-13-67	Time Signal Generator		x		x
61	1	1-13-67	Time Signal Generator		x		x
62	1	1-13-67	Time Signal Generator		x		x
63	1	1-16-67	Yoke Assy — Shock Absorber		x		x

NOTE: Reports number 1, 2, 3, & 4 occurred prior to Reliability Demonstration first flight.

Reports number 9 & 10 were void.

Reports number 53, 54, 55, 56, & 57 are dated subsequent to last flight required to reach a decision in the Reliability Demonstration.

TABLE III

RELIABILITY DECISION VALUES

Number of Failures	Reject, if test hr less than	Accept, if test hr are
0	---	82.2
1	---	113
2	---	145
3	10	175
4	40	207
5	70	238
6	100	259
7	130	300
8	160	310
9	190	310
10	220	310
11	310	---

TABLE IV

RELIABILITY DEMONSTRATION FLIGHT HOURS FOR AIRCRAFT NUMBERS 60-372, #1 60-375, #2 61-330, #3

Flight Date	Aircraft No.	Flight Hours	Cumulative Flight Hours
10-28-66	1	4:00	4:00
10-31-66	1	1:10	5:10
10-31-66	1	3:10	8:20
11-03-66	1	3:30	11:50
11-08-66	1	6:25	18:15
11-12-66	1	6:50	25:05
11-14-66	1	7:00	32:05
11-22-66	1	3:50	35:55
11-29-66	3	6:15	42:10
11-30-66	1	6:00	48:10
12-03-66	1	6:50	55:00
12-07-66	1	5:15	60:15
12-13-66	1	6:30	66:45
12-15-66	2	1:00	67:45
12-20-66	2	5:55	73:40
12-22-66	1	4:30	78:10
1-04-67	1	5:15	83:25
1-07-67	1	6:00	89:25
1-11-67	1	7:35	97:00
1-14-67	1	7:00	104:00
1-18-67	1	6:20	110:20
1-21-67	1	6:00	116:20

TABLE V

A/RIA MAINTAINABILITY REQUIREMENTS

Subsystem	A MTTR Reqm't	B Predicted ($x10^6$)	A x B
PMEE Cooling	1.1 hr	526	579
Electrical Power	1.15 hr	3,323	3,821
Interphone	.9 hr	3,610	3,249
Oxygen	1.8 hr	6,741	12,134
Trailing Wire Antenna	1.2 hr	3,333	4,000
Total System	1.36 hr	17,533	23,783

TABLE VI

AIRCRAFT MODIFICATION SUBSYSTEM MTTR

Item	Remove/Replace Time in Hours	Predicted Failure Rate (x 10 -6)	Number of Remove/Replace	N T	N
Trailing Wire Antenna	1.5	3,333	22	109,989	73,326
Antenna Control	0.33	3,333	6	6,599	19,998
Antenna Coupler Control	0.5	3,333	10	16,665	33,330
PMEE Blower	4.0	526	3	6,312	1,578
Frequency & Load Controller	1.0	3,323	1	3,323	3,323
Generator Control Panel	1.0	3,323	1	3,323	3,323
Voltage Regulator	1.5	3,323	1	4,985	3,323
Oxygen Regulator	1.0	6,741	1	6,741	6,741
Oxygen Bottle Portable	0.16	6,741	1	1,078	6,741
Oxygen Check Valve	0.25	6,741	1	1,685	6,741
Annunciator Panel	0.16	3,610	2	1,155	7,220
Relay, Interphone	1.0	3,610	1	3,610	3,610
Interphone Control	0.33	3,610	2	2,383	7,220
*Radome	3.25	44	11	1,573	484
Total					
Subsystem MTTR = 0.951 hours					

*Excluded from subsystem MTTR computation

N = Number of tasks

T = Remove/Replace $MTTR = \frac{NT}{N}$ = Failure Rate

ANNEX A

FLIGHT BY FLIGHT FAILURE RECAP

Aircraft No. 1, S/N 60-372

Flight No. 3, 10-28-66

No applicable failures.

Flight Nos. 4 and 5, 10-31-66

Discrepancy: Airflow vane of receiver filter shelf would not allow Receivers 2 and 3 to operate. Failure Report No. 5.

Discussion: The airflow interlock vane jammed indicating a false condition of no airflow. The spring loaded vane operates a micro-switch which shuts power off the receivers if no airflow is received. Even though the vane was jammed against one side, airflow was still being received due to its location in the air passage way. Nevertheless, the two receivers were shut down and the failure scored as a system failure. Two of the three receivers must operate for system success. The cause of jamming is attributed to mid-flight turbulence. A production fix has been made to prevent recurrence.

Flight No. 6, 11-3-66

Discrepancy: TLM position countdown clock display units of minutes count #2 up all the time.

Discussion: Checked O. K. on ground.

Flight No. 7, 11-8-66

Discrepancy: VHF verification voice very distorted.

Discussion: Transmitter oscillator retuned. Not a valid failure - only a quality condition. Not a system failure. Various alignments were utilized in an effort to define operational parameters.

Discrepancy: UHF RHC track receiver not tracking.

Discussion: Receiver phasing corrected. Can be rephased in flight. Not a system failure. Various alignments were utilized in an effort to define operational parameters.

Discrepancy: VHF RHC track receiver no auto track signal.

Discussion: Receiver was checked on post flight and checked O. K.

Flight No 7. 11-8-66 (Continued)

Descrepancy: VHF voice transmitter not keying properly.

Discussion: VOX units were adjusted. VOX units must be adjusted to individual operator's voice. This can be done in flight. Not a system failure.

Discrepancy: Need intercom balance, intercom levels from flight crew not high enough; and intercom levels vary widely and cause over-driving transmitters.

Discussion: Although the conditions were not desirable, it is not a system failure. The interphone subsystem was later modified by ECP 0047 which improved the subsystem's performance. Not a system failure.

Discrepancy: HF power amplifier No. 1 fluctuating output.

Discussion: Transmitter was retuned. Various alignments were utilized in an effort to define operational parameters. Not a system failure.

Flight No. 8, 11-12-66

Discrepancy: Track Receiver #3 no auto track indication.

Discussion: Auto track of GT-12, Orbit 14, would not work on VHF RHC. VHF LHC was selected but tracking was very unstable so manual track was selected and continued through the data run. Not a system failure. Solid VHF LHC auto track was secured on Orbit 15. The track receiver had trouble on Flight No. 7. Due to the shortness of time between flights for Gemini, the receiver was not sent to the lab for check-out and repair but rather was switched with Receiver No. 2 for the upcoming flight (Flight No. 9). Also, this method was thought to be an aid in trouble shooting.

Discrepancy: Recorder #2, Channel 13, record level control lock stuck.

Discussion: At this time in the program procedure was to set during preflight and then reset in flight if necessary. The condition was corrected on the ground by loosening the deviation pot with silicon lubricant and a hand tool. Not a system failure. Channel 13 was not lost.

Flight No. 9, 11-14-66

Discrepancy: Track Receiver #2 did not give auto track closure to tracking combiner during calibration. Failure Report No. 13.

Discussion: This is the same track receiver problem as in Flights 7 and 8. The flight was configured as a VHF flight. Not a system failure. The problem was found to be a bad lock relay.

Flight No. 10, 11-22-66

Discrepancy:	PMEE cooling system automatic control (temp.) valve does not work in the auto position. This valve works only in the manual mode.
Discussion:	Broken wire repaired. Not a system failure. Redundancy in the temperature controller allows the temperature control valve to be operated in either the automatic or manual mode.
Discrepancy:	PMEE blower failed. Failure Report No. D18902.
Discussion:	Main blower failed. Mission was completed with auxiliary blower. Not a system failure. Redundancy allows either blower to be operated or both. This was a prototype blower; production blowers had not yet been installed.
Discrepancy:	Tracking Demodulator.
Discussion:	The UHF tracking receiver No. 2 tracking demodulator (PMD) was replaced prior to Data Run No. 2 with the receiver giving the proper lock signal. The receiver was also rephased, using the in-flight alignment procedure. Not a system failure. Spare PMD units are carried on board.
Discrepancy:	HF Receivers #2 and #3 high noise level.
Discussion:	System checked on ground and operated normally.
Discrepancy:	HF receiver loss of Channel B1. Failure Report No. 15.
Discussion:	Bad output stage on dual audio amplifier. Not a system failure per Math Model Page 24 of A/RIA TN No. A0160.

Flight No. 11, 11-30-66

Discrepancy:	Generator #3 cycles 430 during engine start. Unable to manually parallel. Post flight check shows cycles to be normal.
Discussion:	Frequency and load controller installed. Failure in flight would not be a system failure as three of four generating lines must operate for mission success.
Discrepancy:	LHC Track Receiver #2 failed. No. AGC.
Discussion:	Tracking error demod replaced. Not a system failure. Tracking can be continued two ways: (1) By RHF if the vehicle is transmitting. (2) If the vehicle isn't transmitting RHC, the RHC receiver can be repatched at the RF panel to accept LHC.

Flight No. 11, 11-30-66 (Continued)

Discrepancy:	No input to VHF voice combiner #2.
Discussion:	Repair was made to a contact relay. Not a system failure due to patching capability redundancy. Reference Math Model Page 16 of A/RIA TN No. A0160.
Discrepancy:	HF Signal Generator inoperative. Fuse blown.
Discussion:	Non-in-line PMEE equipment.
Discrepancy:	Antenna appears not to stow even though stow lock indicator lights.
Discussion:	Antenna was stowed elevation-wise but not azimuth-wise. The stow pin was realigned. Not a system failure. As long as the antenna is stowed elevation-wise, it will not interfere with operation of the APN-59.
Discrepancy:	Power Amplifier 0A20-4, will put out only 200 watts of power. Failure Report No. 24.
Discussion:	Not a system failure. Two of three required, per Math Model Page 24 of A/RIA TN No. A0160.
Discrepancy:	Power supply on wide band Recorder #1 intermittent.
Discussion:	Checks O.K. on ground. Problem was cleared in the air. The operator cleared the vane by hand and operation was resumed. Item was written to assure checking it on the ground.

Flight No. 12, 12-3-66

Discrepancy:	No. 3 generator drops out of parallel intermittently in flight when one or more of the other generators is tripped.
Discussion:	Frequency and load controller needed adjustment. Not a system failure. Three of four generating lines must operate for mission success.
Discrepancy:	No. AGC at antenna console on VHF LHC.
Discussion:	Loose cable reconnected. Presence of signal could be verified by intercommunication with voice control during manual track operation. Also, signal error meters would deflect indicating presence of a signal. Not a system failure.
Discrepancy:	Battery Power Supply, timing will not drive prime frequency standard.
Discussion:	Logic card in power supply replaced. Not a system failure, due to redundancy per Math Model Page 25 of A/RIA TN No. A0160. Battery power supply is used for emergency back-up power.

Flight No. 13, 12-7-66

Discrepancy: The pilot had trouble getting ignition on Engine No. 3. During normal starting sequence the amps were reduced to a degree where No. 3 would not start. The engines were shut down, restarted on external power and in a different sequence. The flight was then accomplished successfully. Check-out after the flight resulted in units being removed from two different generating lines: (1) No. 3 voltage regulator and a pressure switch on constant speed drive; (2) No. 4 Generator Control Panel. Failure report Numbers D18921 and 356420.

Discussion: The units were not scored as system failure since there was not a loss of any generating line in the air and the mission was successfully accomplished.

Discrepancy: MCC airflow failure light came on with one or both blowers on.

Discussion: Could not duplicate - checks O. K. on ground. All equipment continued to operate normally.

Flight No. 14, 12-13-66

Discrepancy: No interphone conversation available between MCC position and cockpit. Cockpit could hear MCC.

Discussion: Not a system failure. With interphone selector set on interphone PMEE, in either pilot or co-pilot position, operator could talk to MCC position. Operator did not have selectors correct.

Discrepancy: Audio Recorder Power "ON" - "OFF" switch defective.

Discussion: Not a system failure. The switch would still work but worked hard. It might take 4 or 5 punches to turn it on or off. Audio recorder was on and worked fine for this flight.

Discrepancy: Wide Band Recorder #1 +18 V. and +20 V. lights out.

Discussion: Not a system failure. A broken wire and light bulbs were replaced. The recorder has not failed, only the indicators. Plus 18 and plus 20 volts were available to the recorder.

Discrepancy: Intermittent AGC, Track Receiver No. 1, to antenna tracking combiner.

Discussion: Worked O. K. on the ground. Later discovered to be a cable problem (refer to Flight No. 19). Presence of signal could be verified by intercommunication with voice control during manual track operation. Also, signal error meters would deflect indicating presence of signal. Not a system failure.

Flight No. 14, 12-13-66 (Continued)

Discrepancy: No. 4 track receiver head appears erratic (first local Oscillator).

Discussion: Replaced the head with spare unit on board. UHF has three spare heads on board depending on mission parameters. Not a system failure.

Flight No. 15, 12-22-66

No applicable failures.

Flight No. 16, 1-4-67

Discrepancy: VHF transmitter requires more than 0 dBm for proper modulation.

Discussion: Proper modulation level was not established during preflight. The voice input from the audio control panel was raised to + 3 dBm average with satisfactory operation. Not a system failure. Item was written so that proper level would be established for the next flight.

Discrepancy: VHF LHC AGC open to antenna control.

Discussion: Complete inspection of AGC signal line on ground. No problem found. Later discovered to be a cable problem (refer to Flight No. 19). Presence of signal could be verified by intercommunication with voice control during manual track operation. Also, signal error meters would deflect, indicating presence of signal. Not a system failure.

Discrepancy: HF Transmitter No. 1, A2 mode (upper - upper side band) does not work.

Discussion: Redundancy for transmitters allows two of three to operate. Not a system failure. Reference Math Model Page 24 of A/RIA TN No. A0160.

Flight No. 17, 1-4-67

Discrepancy: No failures.

Discussion: Night landings. No time charged for the Reliability Demonstration time.

Flight No. 18, 1-7-67

Discrepancy: VHF transmitter carrier on indicator light intermittent.

Discussion: Transmitter ground checked O.K. Condition was probably because VOX-Anti-VOX was not set up right. This would cause the voice and the light to cut off quicker than normal. Needs to be set for voice of particular operator. Not a system failure.

Flight No. 18, 1-7-67 (Continued)

Discrepancy:	OA9-5 H. P. counter not operating correctly.
Discussion:	Bad counter head repaired by Bendix. H. P. counter head failure does not constitute system failure because with manual sweep end observing lock on indication on meter of receiver, the transponder could be locked on.
Discrepancy:	Track Receiver No. 1 no lock indication.
Discussion:	Ground checks O. K. The problem could not be verified.
Discrepancy:	RF Translator will not allow transmitter to tune in 17 MHz range. Failure Report No. 58.
Discussion:	RF tuner switch not making ground. Not a system failure. Redundancy for transmitters allows two of three to operate per Math Model Page 24 of A/RIA TN No. AO160.

Flight No. 19, 1-11-67

Discrepancy:	Wide Band Recorder No. 1, end of reel sensor light burned out.
Discussion:	Reel would keep running. Could be shut down manually. Not a system failure.
Discrepancy:	Track Receiver No. 2 no tracking error.
Discussion:	Checked O. K. on ground. Failure not verified.
Discrepancy:	Track Receiver No. 1 no AGC indication to antenna console.
Discussion:	Shorted coax cable in jack in receiver panel. This is the same problem as in Flights 12, 14, and 16. This was the main cause and the problem was finally solved. Not a system failure as the presence of signal could be verified by inter-communication with voice control during manual track operation. Also, signal error meters would deflect, indicating presence of a signal.

Flight No. 20, 1-14-67

Discrepancy:	TLM Receiver No. 6 no AGC.
Discussion:	Not a system failure. Five of six must work with repair per Math Model Page 15 of A/RIA TN No. AO160.

Flight No. 21, 1-18-67

Discrepancy: AGC operation on HF Receiver No. 1 and 2 not correct on low signal level.

Discussion: Discrepancy was noted on preflight check-out and is an alignment problem. Not a system failure. Units were used on the flight, operation was satisfactory but did not meet preflight specification.

Discrepancy: No emergency voice out of Signal Data Demod No. 1.

Discussion: The unit was not set up properly during preflight. This was an operator problem, not a system problem. Not a system failure. All that was required after flight was a realignment.

Discrepancy: UHF verification receiver light does not operate properly.

Discussion: Light sensing circuit not correctly adjusted. If light does not work but receiver is working, as in this case, verification may be obtained by the sidetone on the intercom or by voice communication with the spacecraft. Not a system failure.

Discrepancy: Spectrum Display Unit OA9, jittery sweep and low sensitivity.

Discussion: Unit was jittery but was still usable. The unit met its operational commitment. The item was written to correct a minor deficiency and to preclude complete failure. Not a system failure.

Flight No. 22, 1-21-67

No applicable failures.

Aircraft No. 2, S/N 60-375

Flight No. 31, 12-15-66

Discrepancy: Flight aborted due to aircraft pressurization and pitot system problems.

Discussion: Flight time was charged to reliability demonstration as PMEE was on. No failures in aircraft mod. or PMEE. Not a system failure as pertaining to applicable subsystems.

Flight No. 32, 12-20-66

Discrepancy: Tracking Combiner, signal strength meter, no VHF LHC signal strength indication. Failure Report No. 33.

Discussion: Meter movement was sticking. Not a system failure. Meter is a tracking aid. However, presence of signal could be verified by intercommunication with voice control during manual track operation. Also, signal error meters would deflect indicating presence of a signal.

Flight No. 32, 12-20-66 (Continued)

Discrepancy:	Signal Data Demod. Phase lock not good resulting in erratic data. Failure Report No. 34.
Discussion:	Not a system failure. The Signal Data Demod is redundant inasmuch as identical information is taken from both SDD units and recorded. Should the space vehicle be utilizing only one polarization by patching, it could be switched to the serviceable unit.
Discrepancy:	Bearing Indicator, Cockpit, no indication. Failure Report No. 35.
Discussion:	Mission coordinator could direct pilot. Not a system failure.

Aircraft No. 3, S/N 61-330

Flight No. 2, 11-29-66

Discrepancy:	Stow unlock appears to be sticking in antenna.
Discussion:	Stow assembly removed and checked for burrs - cleaned with crocus cloth. Not a system failure.
Discrepancy:	LHC VHF - no tracking.
Discussion:	Not a system failure. Track receiver rephased in flight.
Discrepancy:	VHF loses track beyond 45°.
Discussion:	Cable was crossed on OA-4. Capability was limited but not a system failure. MCC could direct the pilot to keep the vehicle within tracking capabilities.
Discrepancy:	LHC VHF - no tracking appears, low gain.
Discussion:	Tracking error demod. replaced. Not a system failure. Tracking can be continued in two ways: (1) By RHC if the vehicle is transmitting. (2) If the vehicle isn't transmitting RHC, the RHC receiver can be repatched at the RF panel to accept LHC.

APPENDIX VII

PERSONNEL SUBSYSTEM TEST AND EVALUATION

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APPENDIX VII

PERSONNEL SUBSYSTEM TEST AND EVALUATION (PSTE) CATEGORY II TEST REPORT

FOREWORD

This report is submitted under Air Force Contract 19(628)-4888, DD1423 Data Item 086, in accordance with AFLC/AFSC Form 9, number T-26-58.0-1. Significant processes and products of A/RIA Personnel Subsystem development, testing, and evaluation are documented for the period 1 March 1966 through 10 March 1967.

ABSTRACT

The Personnel Subsystem Test and Evaluation (PSTE) Category II Test was performed in accordance with test criteria in AFR 30-8, MIL-H-27894A (USAF), AFR 80-14, and AFSCM 80-3. The primary objective of PSTE is to verify that qualified operating command personnel can effectively activate, operate, maintain and control the A/RIA System in its intended mission and/or alternate mission ground and flight environments.

Category II PSTE test objectives were:

a. Personnel Performance and Proficiency.

b. Technical Order Verification.

c. System Operational Capability.

Category II flight operations provided sufficient numbers of PMEE system functional performance demonstrations, under controlled test conditions for PS Observer/Evaluators to obtain personnel performance data to complete the test objectives with the exception of Tests 2-14, 2-17, and 2-18 (see Section II for numbered test exceptions). Refer to SS100000, paragraphs 4.2.1.3.1 and 4.2.1.3.2 for PS test requirements; TU 28325 and DAC 56171 for implementation.

The following abbreviated summary of PS findings and conclusions is based on test results as well as emprical knowledge:

a. The capability of "operational" (AF crews) to perform all "primary" system functions has been adequately demonstrated and is considered completely verified with high confidence by PSTE.

b. Maintenance capability was not demonstrated. No evaluation of malfunction/corrective area can be based on actual data. However, a maintenance capability evaluation can be based on PED activities, e.g., PMEE Design Review, trouble-shooting exercises using PMEE manuals and Bendix drawings and task analysis preparation, etc.

Assuming inherent maintenance capability and conditions at AFETR, actual capability to maintain the system at all three levels of maintenance is considered to be adequate.

c. It is recommended that AF Personnel and Training document be changed to reflect the following:

(1) Five in lieu of seven levels are adequate for crew positions for mission (CO) operations as shown:

Positions 4 and 5 – one 7 and one 5 level

Positions 3 and 6 – 5 levels

Positions 2 and 7 – 7 levels

(2) Position 3, Antenna Control Operator, AFSC should be changed from 30373 to 31750.

(3) Position 1, Mission Coordinators, should have a new or different AFSC, Title, and/or at least a new suffix to identify this position, i.e., this is more than a ground avionics Maintenance Officer's position.

SECTION I

INTRODUCTION

1.1 OBJECTIVE

The overall PS program and the individual PS element programs have, as their general objective, the development of that aggregate of hardware, software, and trained personnel which will promote maximum system efficiency under design constraint limitations. This broad objective is translatable into element objectives as indicated in the following sections of this report. Further, it is intended to convey the following competent PS disciplines:

a. Verification status of PS elements and test objectives at the conclusion of Category II testing.

b. PSTE baselines for Category III testing.

1.2 SCOPE

The Personnel Subsystem effort incorporates all the analytical, experimental, research, design, testing and evaluation activities conducted by PS specialists in the process of providing for human components of the system. In varying degrees, all of the skills, techniques and procedures of various specialties, as described in AFSCM 80-3 (Handbook of Instructions for Aerospace Personnel Subsystem Design), were applied in the conduct of this program.

This report encompasses the following PS functional areas in which development, documentation, test, and/or evaluation tasks were performed between March 1966 and March 1967, by PS disciplines at Douglas and/or Bendix contractor or subcontractor facilities.

These tasks were interrelated with and paced by hardware and "other" development, documentation, test and/or evaluation activities which occurred during the same period of calendar time in the acquisition phase of the 435A System Program.

Prime areas of PS activity at Douglas were:

a. Personnel Equipment Data (PED), i.e., PS data gathering and analysis.

b. Human Engineering (H/E) and Life Support (L/S), i.e., Category I PSTE.

c. Personnel Subsystem Test and Evaluation (PSTE), i.e., Category II PSTE.

d. "Others," i.e., plans, procedures, reports, meetings, coordination visits and administration.

Bendix activities were in these four areas, plus two other areas called out in AFSCR 80-16, i.e., "System Personnel Requirements," and "System Training Requirements." (See AFSCR 80-16 for PS elements included in these "functional areas.")

The implementation of personnel subsystem development required that human engineering design personnel perform their tasks from the beginning of the A/RIA systems analysis effort through testing and evaluation. The initial PS effort required the completion of Requirements Allocation Sheets (RAS). The RAS basically contain an analysis of the functions depicted in the functional flow diagrams. By determining the human performance task requirements, time required to complete the task, performance demands, the allocation of functions, task identification, training and training equipment requirements, as well as documentation requirements, personnel subsystem requirements are incorporated into the A/RIA system analysis.

This implementation satisfies AFSCM 375-5, AFSCM 310-1B and MIL-H-27894A A/RIA contractual requirements.

The implementation of personnel subsystem development required the development and utilization of personnel equipment data and human engineering techniques. These techniques involved analysis of:

a. Information the operator needs.

b. Communications he needs for information flow.

c. Displays he needs to organize information into usable form.

d. Controls required for appropriate responses to information received.

The methods employed to perform this analysis consisted of techniques such as task analysis, link analysis, and time line analysis. In performing this analysis the operator tasks were examined in order to define operator procedures, estimate operator workloads, estimate system and operator response times, and predict the frequency and criticality of operator errors.

The physical properties of each operator station were examined to ensure the validity of workspace layouts, compatibility of the system with appropriate anthropometric considerations, and appropriate operator environmental considerations.

Life support consideration was also incorporated into design requirements in order to adequately implement personnel subsystem development. These include determination of personnel in-flight equipment requirements, escape and survival requirements, and safety provisions.

The analysis activities described previously are documented, forming part of the PED file which is the central storehouse of PS data.

SECTION II

SUMMARY

The basic objective of PSTE is to verify that qualified operating command personnel can effectively activate, operate, maintain and control the A/RIA System in its intended mission and/or alternate mission ground and flight environments. PS tests were made to insure that equipment, skills, procedures, support, and technical data adequately provide and support performance within specified constraints.

The specific Category II test objectives were:

a. Personnel Performance and Proficiency — To verify the proficiency of operational personnel, and performance of the equipment in all A/RIA System test operations.

b. Technical Orders (Procedures) Validation — To verify the technical adequacy of Technical Orders which support A/RIA System Personnel Performance of operations and maintenance tasks.

c. System Operational Capability — To verify the capability of the operations and maintenance crew to accept the A/RIA System at the termination of the Category II Test Program.

These objectives were achieved through compliance with the numbered tests contained in DAC TU-28325, dated January 1966, revised 25 March 1966. Exceptions to this are numbered tests 2-14, 2-17, and 2-18. It is recommended that these tests be carried out during Category III Testing. (See Section IV, Maintenance Proficiency.)

During Phase III, Operational Proficiency, sufficient observations were made and data collected to verify tests No. 2-11 through 2-15 and No. 2-19, and further qualified by interviews conducted by contractor personnel with AF operations and maintenance crews.

Test No. 2-16 was accomplished and verified during Technical Order Verification conducted at Douglas, Tulsa.

SECTION III

DOUGLAS CATEGORY I PSTE

3.1 HUMAN ENGINEERING AND LIFE SUPPORT VERIFICATION

3.1.1 Objectives

Human Engineering/Life Support evaluations were made to verify that system equipment characteristics, as designed, comply with HE/LS design criteria specified in the Part I CEI Specifications.

3.2 IMPLEMENTATION

PSTE to accomplish this objective was performed in the following sequence and manner (Reference TU-28325).

a. CEI Specification Review – Test No. 1-1.

b. Engineering drawing review and evaluations – Test No. 1-2.

c. Direct participation in all Design and Critical Design Reviews (CDR's) – Tests No. 1-1 and 1-2.

d. Mock-up tests and evaluations – Test No. 1-8 which includes applicable parts of Tests No. 1-3, 1-4, and 1-5.

3.2.1 Test No. 1-1 – CEI Specification Review

All A/RIA Part I CEI Specifications were reviewed to insure the incorporation of all the applicable sections of Douglas Drawing No. A100211 and/or MIL-STD-803A-1, AFSCM 80-1, and AFSCM 80-3 as a required design consideration. An up-to-date CEI Specification Review Record/Checklist has been completed and is a part of the PED File (Data Item 300).

3.2.2 Test No. 1-2 – Engineering Drawing Review and Evaluation

Equipment drawings evaluations were made using a checklist adapted from the requirements specified in Douglas Drawing A100211 and MIL-STD-803A-1. The checklist, entitled "Integrated Aircraft Modification and PMEE Human Engineering Design Compliance Checklist No. 1," was designed to be used in the evaluation of actual hardware as it became available. For all items of non-compliance to the checklist, Deviation/Difficulty (D/D) forms have been written, made a part of the PED File, and forwarded to Bendix Radio for their review and action. As the actual hardware was received at Douglas, these same checklists were completed for those items which require actual hardware for a meaningful evaluation.

3.2.3 Test No. 1-1 and 1-2 – Critical Design Reviews (CDR's)

The A/RIA Personnel Subsystem Group HE/LS representative was an active participant at all Critical Design Reviews conducted at both Douglas Aircraft, Tulsa, and at Bendix Radio, Baltimore, Maryland. The objective, during

these reviews, was to verify that the design presented in response to the requirements set forth in each A/RIA System Part I CEI Specification was in compliance with the criteria specified in Douglas Drawing A100211, as well as with other human engineering/life support criteria in accordance with MIL-STD-803A-1 and AFSCM 80-3. The methods used during these reviews included:

a. Completion of the Configuration Manager's checklist provided specifically for the CDR for each CEI.

b. Evaluation and inspection of the actual hardware, when available.

c. Review and evaluation of panel layout drawings for each equipment item associated with the CEI being reviewed.

d. Review of supporting data, when available, i.e., task analyses, human engineering recommendation sheets on panel layouts, etc.

3.2.4 Test No. 1-8 – Mock-up Tests and Evaluations

A static mock-up of the EC-135N Aircraft, including the external shells of PMEE cabinets, racks and consoles forming the A/RIA configuration was developed at Douglas, Tulsa. It was this mock-up that was used for the Category I Human Engineering/Life Support evaluation and testing. The mock-up was made of wood with full-scale panel layout drawings pasted to the cabinets and consoles. For workspace evaluations and anthropometric measurements, the seat positions for each operator were marked on the floor of the mock-up and a Navigator's seat from a C-135 Aircraft placed in the marked position. All evaluations and measurements were made with a PSTE observer seated in the normal operator position at each A/RIA crew position. In addition, the mock-up permitted evaluation of some integrated aspects of the A/RIA System, such as wiring, ducting and access for maintenance, which would not have otherwise been available until the completion of the Number 1 aircraft. The equipment characteristics evaluated, using Checklist No. 1, mentioned above, and Checklists 2 and 3 included the following:

a. Placement of individual modules relative to each other – Test No. 1-5 (ref).

b. Location of controls and displays relative to anthropometric limitations of operational personnel – Test No. 1-5 (ref).

c. Accessibility to equipment assemblies – Test No. 1-5 (ref).

d. Location of, and access to, test points, cabling, connectors and ducting – Test No. 1-5 (ref).

e. Amount of workspace available for operational personnel – Test No. 1-4 (ref).

f. Personnel and equipment safety – Test No. 1-3, 1-4, and 1-5 (ref).

3.2.5 Test No. 1-9 — System Integration Test

The purpose of the integration testing was to verify that HE/LS requirements were not changed or compromised during the hardware fabrication and installation processes, i.e., that system hardware AVE/AGE were fabricated and installed in accordance with designs which were previously approved for HE/LS requirements.

In order to fulfill completely the (PS) objectives of the System Integration Test, three checklists were generated to cover all necessary areas of Douglas Drawing No. A100211 and/or MIL-STD-803A-1. These three Checklists are:

a. Aircraft Non-Operating Location
   (1) Life Support/Environmental Factors
   (2) Safety Criteria

b. Aircraft Operating Location
   (1) Auditory Displays
   (2) Workspace Design
   (3) Safety Criteria

c. Aircraft Maintenance Location
   (1) Workspace Design
   (2) Design for Maintainability
   (3) Safety Criteria

Checklists were used during A/RIA Category I Aircraft Interior testing. Personnel Subsystem inputs to the overall Aircraft Interior Test Plan and Procedures were submitted to the Development Test Group (12 September 1966).

3.2.6 Test No. 1-10 — Technical Order Coverage

The (PS) objective was to verify that there are Technical Orders to cover all A/RIA System operations defined in the FFD's and RAS's.

Since the A/RIA Bendix and Douglas FFD's and RAS's generated during PDP do not adequately cover the present A/RIA Mission configuration, they were not used as the main criterion for evaluating the adequacy or accuracy of A/RIA Partial Technical Orders.

Criteria consisted of the basic Technical Order for which the A/RIA Partial was written, the applicable A/RIA Part I CEI Specifications dictating changes to the basic, Engineering Drawings (SCD's, ICD's, etc.) used to support the CEI's, the System Specification (SS100000), and, where possible, PDP FFD's and RAS's.

Review comments and reports were documented, and are a part of the PED file.

3.3 RESULTS

3.3.1 Test No. 1-1 – CEI Specification Review

Douglas Drawing A100211 is referenced in the appropriate sections of each CEI Specification (APPLICABLE DOCUMENTS, paragraph 2.0), (Requirement, paragraph 3.1.2.6), and (Quality Assurance Document, paragraph 4.0). The exception is CEI CP100006A, Inventory Items for A/RIA.

3.3.2 Test No. 1-2 – Engineering Drawing Review and Evaluation

Reviews and evaluations have been completed for all PMEE equipment and aircraft modification man-machine interfaces, using one or more of the checklists. The completed checklists have been made a part of the A/RIA Personnel Subsystem PED File at Douglas-Tulsa. Areas of non-compliance discovered during these evaluations have been recorded on D/D forms which have also been made a part of the PED File. Copies of D/D's pertaining to the PMEE equipment were forwarded to PSS personnel at Bendix Radio for review and appropriate action prior to the Critical Design Reviews. Those D/D's pertaining to the aircraft modification were coordinated with the appropriate design groups at Douglas. In the review of PMEE equipment drawings, evaluations were initiated as early as possible using the best available drawings, and then revised as more up-to-date drawings were received. In some instances, these early drawings were no more than sketches or reproduced illustrations or photos from commercial vendors' manuals. However, as more up-to-date drawings were received, evaluations were updated.

Checking the A100211 paragraphs for which most non-compliances appear, reveals that the majority of deviations noted fall into four categories. These categories are:

a. Location of Controls.

b. Transilluminated Indicators.

c. Labeling.

d. Failure Indication and Fuse Holder Requirements.

In addition, the majority of deviations are associated with commercial "off-the-shelf" items within each Operating Assembly (OA).

As a result of all Category I HE/LS activities to date, a total of 56 requests for deviation and/or waiver from the human engineering design requirements of Douglas Drawing A100211 have been submitted to the A/RIA System Program Office at ESD. Approval has been received on all of the requests.

Review of the Bendix-originated requests submitted to ESD for consideration shows that here, as in the evaluations performed by Douglas using Bendix-submitted drawings, the majority of non-compliance items are associated with commercial "off-the-shelf" equipment. The criterion areas for which ESD disapprovals have been received are as expected in the areas of handles, control markings, red power indicator lights and fuse requirements. These

four areas are typically some of the "weak points" of all commercial equipment when it is evaluated against the established human engineering criteria generally imposed on Military contracts.

3.3.3 Tests Nos. 1-1 and 1-2 – Critical Design Reviews

The Douglas PSS HE/LS representative participated in all A/RIA Critical Design Reviews and served as the Chairman of the Human Factors, Maintainability, Safety and Reliability Committee sub-meetings at all reviews. However, the discussion presented here deals primarily with the Human Factors area, except where overlap with the other discrepancies occurs. The results of each CDR are presented in the order of their occurrence.

3.3.3.1 4 March 1966

CP 100008A, Intercommunication Set

CP 100076A, Isolation Amplifier Control Unit

CP 100009A, Nose Radome

During this review, there were no human factors problems associated with the review of CP 100076A or CP100009A; however, several problems were revealed in the review of the Intercommunication Set, CP100008A. The problems discussed and the resolutions presented were as follows:

Problem:

The nomenclature on the annunciator panel and interphone selector switch is such that all positions do not have the same letter designation for a specific function.

Human Factors proposed a revision to the engraving on the annunciator panel and the selector switch.

Resolution:

It was stated that position designations would be revised in accordance with "inked" drawing J100575, included in the drawing package.

Final Disposition:

The proposed revision was accepted and the present ICS equipment incorporates the recommended changes.

3.3.3.2 4 April 1966

CEI 100021A – Valve, Temperature Control

CEI 100040A – Fan, Cooling, Electronic Equipment

No deviations to the approved Part I CEI Specification were evidenced in the CDR. Due to the location of the cooling fan (aft baggage compartment, Station 1280), the HE/LS representative questioned the noise level of the

fan motor. Review of the manufacturer's data on the motor revealed a noise level of approximately 70 dB. This should be verified during the noise level measurements on the first aircraft. The concern here is that this is in the vicinity of the aft crew rest area, where it is desirable to keep the noise level as low as possible. If the manufacturer's estimates are correct, there should be no problem as far as the motor is concerned, since the ambient noise level of this area will be higher than 70 dB.

3.3.3.3 18 April 1966

CEI 100034 – Bar, Towing and Steering

The only HE/LS problem associated with the review of the tow bar (CEI 100034) design had to do with its weight. The tow bar must be removed from the tug or tractor, manually rolled up to the airplane, and then reattached to the tug due to the configuration of the radome. The dead weight lift to hook onto the tug is 240 pounds. The HE/LS recommendation was that a CAUTION note be affixed near the lifting handles/attach point stating the weight and the words "CAUTION – FOUR MEN REQUIRED TO LIFT." Review of the design drawings revealed that the handles provided are large enough to accommodate five men.

3.3.3.4 9 to 10 May 1966

CEI 100001A – Aircraft Modification Subsystem

The Aircraft Modification Subsystem Critical Design Review was the first in which the Human Factors, Reliability, Maintainability and Safety Committee was broken away from the main groups to hold a separate review covering the areas of concern for each discipline. The participating Government agencies were also represented in the meeting.

A major problem area, or area of concern, which developed during the review pertained to the stowage provisions aboard the aircraft. The participating Government personnel agreed that Douglas had met specification requirements in terms of stowage; however, it was their recommendation that survival equipment stowage be reduced to eliminate aisle congestion. The cutomer recommended that stowage for the eight crew rest positions and the Record/Timing Operator positions be provided on the aft port side at Stations 950 to 1100. It was pointed out that this would conflict with the existing specification requirements to provide for future PMEE growth in the same area. It was further requested, by personnel from AFETR, that provisions for tie-down rings be provided in two areas. One area on the port side aft between Stations 950 and 1100, the other forward on the starboard side in the ALOTS Console area. It was stated that these tie-downs were desirable to make use of unused space for additional crew baggage and spare parts stowage. This request for tie-downs has been met. The engineering is complete for the tie-downs at Stations 950 to 1100 and all aircraft modified so far are so equipped. ECP 0034 has been approved to provide the tie-downs in the ALOTS area.

Another problem area brought forth in the review was the inability of any PMEE personnel, with the exception of the MCC, to talk to the pilot except by using the emergency position. Government representatives felt that a

capability, separate from the use of emergency, should be provided to allow everyone in the aircraft to talk to the pilot. The final outcome was that the SPO representatives suggested Douglas submit an ECP for incorporating the requested change to the ICS. ECP 0035, covering this item, was submitted to ESD. Disapproval of the ECP was received on 25 August 1966, stating that the work requested in the ECP was not considered essential.

A review of the mock-up by CDR participants brought up the problem of crew helmet stowage. The mock-up provided for stowage of these helmets near the survival equipment racks. It was pointed out that an explosive decompression would not permit the time for personnel to leave their positions and obtain their helmets to hook into the GOX system. In addition, AFR 60-16 requires that the stored helmets be readily accessible to personnel. This helmet stowage has now been changed to provide for each operator's helmet to be hooked to the GOX system and stowed at the console.

3.3.3.5 15 June 1966

CP 100003A, CP 100090A, CP100091A – Timing Subsystem

During this review, the CEI specification paragraphs relating to reliability, maintainability, safety and human factors/personnel subsystem were reviewed and the CDR checklists completed for each discipline.

Concern was voiced by Douglas as to the weight of the Dual Power Supply and the Battery Power Supply. Bendix offered a drawing for review which showed the weight of these units as 95 pounds each with adequate provisions for two-man lift. However, since the time of the review, it has been learned that the weights involved are more like 175 pounds. A simple cart would suffice for this purpose, but its use is prevented by the floor hump located directly in front of the timing system. This hump became necessary after the design of the timing system was complete.

These batteries are of the nickel-cadmium variety and will not need removal for service more than once a year. In this case it would seem that a great deal of inconvenience could be accepted in their removal. In addition, it should be considered that the batteries are accessible for routine maintenance and that one battery at a time can be removed. This item was satisfactorily demonstrated to ESD on 28 April 1967. No further contractor action is required.

As a result of the above problem, Bendix was asked about the labeling of all overweight units. The response was that all units over 45 pounds will be labeled over the handles with letters 0.25 inch in height.

Several items of non-compliance concerning provisions for spare fuse holders were also noted in the review of panel layout drawings and Bendix personnel were informed that requests for deviations would be required. A summary of these, along with all other requests for deviation/waiver, and the disposition of these requests, will be discussed at the end of this section of the report, after the results of each CDR have been presented.

3.3.3.6 16 June 1966

CP 100004A – HF Communications Subsystem

A major area of HE/LS non-compliance was brought out at this design review. The Collins Radio equipment included in the HF Subsystem does not meet the requirements of the CEI, paragraph 3.3.1.2, or the requirements of the HE/LS Design Criteria document A100211. The equipment involved is black rather than gray. A request for deviation to the requirement has been submitted by Bendix pointing out the impact to program cost and schedule that having the equipment repainted would impose. The request for deviation has been approved by the Customer, ESD.

3.3.3.7 17 June 1966

CP 100029A – Mission Coordinator's Console

During the review of the MCC design, only one non-compliance item was found. The work/writing surface is 14 inches in depth in contrast to the 16-inch depth called for by A100211. It was also brought out that all of the other console work/writing surfaces are the same dimension. The reason for this is that the space limitations of the aircraft will not permit the 16-inch depth for the writing surface. A request for deviation to the 16-inch requirement was submitted to ESD. Approval of the request was received on 14 September 1966.

3.3.3.8 24 June 1966

CP 100007 – ALOTS

The first item discussed during this review was a deviation proposed by Douglas involving system maintenance. The specification requires that maintenance be performed without requiring the removal of in-the-way items. This requirement cannot be met since access to the rear of the ALOTS Console for hookup or disconnect is through the aft bulkhead of the forward crew rest area. In order to get to the hatch through the bulkhead, the aft seats must first be removed. Drawings of the access hatch were reviewed. The hatch has been made as large as possible and meets the minimum prone crawl space requirement of 17 inches called for in MIL-STD-803A.

During the review, ESD was asked to provide dimensions of the tracker drawer to allow further study of a possible interference problem with the MTS pedestal in the removal and replacement of the drawer. It was decided that if an interference problem did exist, there were two possible solutions. The first would be to hinge a portion of the aft right-hand side of the MTS operator's platform. The second approach would be to remove this portion of the platform rather than hinging it.

The necessary dimensions have been received from ESD and an interference problem did actually exist. The solution adopted was to remove the portion of the MTS platform which prevented the drawer from being removed. Removing this section did not compromise the MTS operator's foot rest area.

One other human engineering/maintainability problem brought forth during this review concerned the installation and alignment of the Console in the restricted space provided. It was admitted that an actual procedure had not been formulated. As a result, the maintainability representative was assigned the responsibility for preparing a proposed procedure based on men, methods and machines. PS personnel participated in the investigation of various methods for accomplishing this task of removal and installation. The proposed procedure has been written by the Maintainability Group and submitted. The method selected involves the use of a forklift. The procedure has been successfully demonstrated using the mock-up.

3.3.3.9 27 June 1966

CP 100010 – Antenna Assembly

During the design review, visual investigation of an Antenna Assembly installed in the Bendix mock-up revealed a problem of accessibility for maintenance or servicing of the vertical reference gyro. Due to the physical location of the gyro within the pedestal and the height of the pedestal from the bottom of the radome, it was determined that maintenance personnel would need either a ladder or some form of maintenance stand when working on or removing and replacing the gyro. There was an additional question as to whether the aircraft would have to be jacked and leveled each time the gyro was removed and replaced. The point was also brought out that at least one of the equipment racks in the forward radome fairing weighed 60 pounds, which presented a problem since the task would have to be performed by one man due to the limited space in the fairing. It was decided that the whole radome/fairing maintenance area was one which required further serious study on the part of Bendix and Douglas.

As a result of the design review, a detailed investigation was initiated by Douglas Personnel Subsystem personnel with inputs from Bendix Radio and Eclipse-Pioneer. Task analyses were performed for removal and replacement of the vertical reference gyro, the APN-59 radar and the antenna assembly modules located in the fairing.

The major problem in the removal and replacement of the vertical reference gyro was, as predicted at the CDR, getting maintenance personnel positioned at an adequate height in the radome. The installation of a ladder on the bulkhead was considered and deemed undesirable from a human engineering point of view since it would not allow the individual performing the remove/replace task to have both hands free. Additionally, the space available on the bulkhead was extremely limited. The method selected was the use of two specially designed removable maintenance access platforms on Station 178 bulkhead. With the use of this stand, the vertical reference gyro can be removed and replaced without any problem. Inputs from Eclipse-Pioneer were analyzed and it was determined that the aircraft would not have to be jacked and leveled each time the gyro was replaced.

Analysis of the APN-59 removal was carried out using a scale paper mock-up. The task will require two men; however, no unique requirements or problem areas were uncovered. No special handling equipment will be required.

The amount of space available in the radome nose fairing is very limited. However, investigation of the fairing area on No. 1 Aircraft revealed that the space provided is sufficien for the accomplishment of the required maintenance tasks. Information received from Bendix nullified the problem of one man trying to lift the TWT equipment rack weighing 55 to 60 pounds. Bendix reported that one or both of the TWT's can be removed from the rack prior to removing the rack itself. Since each of these units weighs an estimated 18 to 20 pounds, their removal reduces the rack weight to a value which can reasonably be handled by one man.

Since the restricted space of the radome fairing did not meet the minimum requirements set forth in the Douglas Drawing A100211, requests for deviation were submitted to ESD. Approval of these requests was received on 14 September 1966.

3.3.3.10 Test No. 1-8—Mock up Tests and Evaluation

A/RIA mock-up tests and evaluations were performed to verify that the aircraft work space environment was in conformance with HE/LS specification requirements and that conditions which could adversely affect safe and adequate personnel performance did not exist. Evaluations were carried out using Checklist No. 2 and covered the following categories:

a. Crew body size (5th to 95th percentile).

b. Sufficient headroom.

c. Passageways.

d. Sharp protrusions.

e. Personnel (crew) seating.

f. Cabinet and consoles.

g. Hand grips and steps.

h. Location of displays.

i. Location of controls.

Obviously, since the mock-up is not a "working" model, only areas which could be evaluated under static conditions were evaluated. Other areas which have yet to be evaluated, e.g., noise level, vibration, illumination and temperature, require input (test results) from Douglas test groups that performed these tests.

Evaluations performed were broken into four logical groupings covering one or more crew operating positions. These four groups, and the crew positions included in each group, are presented below.

a. ALOTS Area
Control Console Operator
MTS Operator

b. RF Area
Telemetry Control Operator (Position 4)
Voice Control Operator (Position 5)

c. Control Area
Mission Coordinator (Position 1)
Antenna Control Operator (Position 3)
HF Operator (Position 6)

d. Record Area
Record Control Operator (Position 2)

The evaluation results for each of the above groups are presented in the following paragraphs:

ALOTS Area

Since the ALOTS equipment is GFE, the evaluations performed were concerned primarily with the provisions for installation and access to the equipment along with crew seating and ingress-egress under normal and emergency operating conditions. Evaluation of preliminary configurations revealed two problem areas which presented conditions considered totally unacceptable from a human engineering point of view. First, the amount of space provided between the Console Operator's position and the MTS pedestal did not adequately provide for the Console Operator's ingress and egress. The situation was considered marginal assuming normal operating conditions. Considering emergency situations and crew escape, this lack of spacing between positions would result in serious safety hazards for the Console Operator. Second, the lack of space between the MTS platform and the ALOTS Console presented limited access to the three DC Power Amplifier drawers for pre-flight setup and/or in-flight maintenance adjustment. Removal or replacement of these drawers appeared to be impossible without first removing the manual tracking pedestal and seat installation.

Following the incorporation of ECP 0030, which moved the MTS installation 20 inches forward, a second evaluation was performed. This evaluation revealed that the increased spacing between the ALOTS Console Operator's seat and the MTS pedestal did provide for adequate Console Operator ingress and egress under both normal and emergency conditions. In addition, the revised configuration provided increased spacing between positions allowing access to the console DC Amplifier drawers located in the lower left-hand corner of the console. With the revised configuration, the two lower drawers could be removed and replaced. The top drawer could at least be extended on its tracks to the near full open position for maintenance and/or adjustment. Also, the pre-flight "setup" of the drawers was made a much easier task since the MTS pedestal was no longer in the way as in the earlier configuration. The second evaluation revealed further that the size of the access hatch in the aft bulkhead of the forward crew rest area provided for hookup of the Console was inadequate. The design group was informed of the problem and the hatch dimensions were increased as

far as physical limitations would permit. (Further problems concerning access for console connection and access for drawer removal are covered in the Critical Design Review discussion.)

RF Area

The RF Group evaluations included the Telemetry Control Operator (Position 4) and the Voice Control Operator (Position 5), which are adjacent to one another and within the same physical workspace. The areas of non-conformance revealed during this evaluation were in the area of available crawl space and spacing between equipment racks. The crawl space deviation, if it can actually be classified as such, concerns the space available under each operator's console. The specification states a minimum height required for crawling of 34 inches. The space provided under each console work surface, where personnel may have to gain access for troubleshooting cabling and wiring, is 30 inches. Actually, this 30 inches is the result of placing the work surface at the height required by the specification. What we have is conflicting specification requirements. Since the operator's work surface is of primary concern, and since the kneewell is not an actual crawl space, the 30 inches provided is considered adequate and does not present a human engineering problem. The problem concerning spacing between equipment racks is simply one where the physical size of the aircraft and the internal space available was insufficient in terms of the amount of electronics equipment to be installed. The specification states that the distance between an equipment rack and an opposite facing obstacle should be at least 42 inches. Here, we have an 803A requirement pertaining to AGE which is simply not appropriate when dealing with the confined space available in aircraft systems. The distance, for instance, between OA4-1 and -2 and OA7-3 and the Voice Control Operator and Telemetry Control Operator work surfaces is 24 inches rather than the specified 42 inches. However, this spacing cannot be increased without cutting down on the crew aisle space which is already at a minimum. This, then, is a justified compromise. The drawers involved can be removed for maintenance and the situation is not considered a serious human engineering problem, even though it does not present the most desirable conditions from a maintenance point of view. The evaluation of control and display locations revealed no areas of non-compliance. The adequacy of crew seating was left as an area to be determined in the actual aircraft, since crew seats were not available for installation in the mock-up.

Control Area

HE/LS evaluation of the HF Group included the Mission Coordinator, Antenna Control and HF Operator positions. Evaluation revealed the same space limitation problems as in the RF Group as discussed above. In addition, the amount of seat adjust for the Mission Coordinator in the aft direction is limited due to the location of the teletype equipment (OA-13). The available aft movement, however, is sufficient for ingress and safe egress during emergency conditions.

A non-compliance, concerning the Antenna Control Operator's Console (OA-11), was discovered during the evaluation. The requirements of A100211 state that precision indicators used frequently and to be read precisely should be placed in an area between 16 and 35 inches above the

sitting surface. The Tracking Combiner panel on OA-11, which contains a number of such indicators, was found to be in an area 37 to 48 inches above the sitting surface. However, the observer found that, seated in a mock-up in a position and height at which the Antenna Operator would be, the panel displays could be read without difficulty. Therefore, it appears that no serious problem exists and a request for a deviation of the specification requirements has been forwarded to ESD. The Request for Deviation (DAC No. 8) was approved by ESD on 29 March 1967.

Record Area

The evaluations of the Record Group revealed the same crawl space and kneeling or bending space areas of non-compliance as the other console positions. Here again, access to this area will be required only when there is trouble in the cabling or wiring. The space provided does not permit adequate access. The crawl space height is 30 inches rather than the 34 inches called for in the specification. The bending or kneeling height would also be 30 inches. The specification calls for 50 inches. As mentioned before in discussing the consoles, the 30-inch height is dictated by the specification requirement for the height of the work/writing surface. The condition does not present a serious human factors problem. In fact, it is questionable whether this under-the-console space or kneewell should even be considered a crawl space.

Evaluations of such areas as colors and the location of controls and displays has been deferred until the receipt of the actual hardware. So much of the equipment involved, e.g., the two data recorders and the audio recorder, is commerical equipment. The only drawings received were illustrations from the manufacturer's technical manuals and these are inadequate for evaluation purposes. The rest of the equipment, especially the Bendix-designed, appears clean and within specification and no HE/LS problems are anticipated.

An additional area evaluated, which did not fall under any of the groupings presented thus far, was the Radome/Fairing areas. The first problem uncovered was that the design did not include a walkway/crawlway for maintenance personnel. This problem was immediately brought to the attention of the Program Office. A change in design was initiated to include an appropriate crawlway in the fairing.

Other areas of non-compliance included the crawl space provided at the access hatch and the bending or kneeling space within the fairing. The space provided for a prone crawl area should be 17 inches. The measurement at the access hatch area is 16-1/2 inches. The kneeling or bending space provided is 38 inches, while the specification calls for 50 inches. Actually, the whole nose fairing area presents a space problem. However, the space available does permit the accomplishment of the necessary maintenance tasks. Request for waiver to the specification was submitted to ESD, with the justification that the space available is the result of optimum aerodynamic design of the radome. Request for Waiver (DAC No. 42) was approved by ESD on 29 March 1967.

3.4 CONCLUSIONS AND RECOMMENDATIONS

In summarizing the Human Engineering and Life Support PSTE effort, it can be said that the major problem area is the PMEE deviations from the requirements of Drawing A100211. The deviations were not unexpected. In order to meet tight schedules and keep costs down, commerical "off-the-shelf" equipment was used whenever possible. Experience has shown that the purchase of "off-the-shelf" equipment cannot be expected to meet the usual human engineering design criteria contained in MIL-STD-803, A100211, or similar documents.

On future programs, it is recommended that deviation to the Human Engineering requirements be granted at the contract level as a blanket release rather than by separate deviation to each specification requirement.

SECTION IV

CATEGORY II PSTE

4.1 OBJECTIVES

4.1.1 Personnel Performance and Proficiency

The objective of Category II PSTE in this area is to verify the proficiency of operational and maintenance personnel, and performance of the equipment in all A/RIA System Test operations. Test No. 2-11 includes verification of:

a. Customer Personnel Requirements — Test No. 2-12.

b. Training — Test No. 2-13.

c. Technical Order usability and suitability — Test No. 2-14.

d. Equipment usability — Test No. 2-15.

e. System operational capability — Test No. 2-19.

4.1.2 Technical Orders (Procedures) Validation

Technical Orders and Procedures Validation is designed to verify the technical adequacy of technical orders which support A/RIA System Personnel Performance of operations and maintenance tasks, both scheduled and unscheduled. Tests include:

a. Technical Order adequacy — Test No. 2-16.

b. System Inspections — Test No. 2-17.

c. Unscheduled maintenance effects — Test No. 2-18.

4.2 SCOPE

The scope of the Category II PSTE is limited to functional performance demonstrations by PMEE operators and maintenance personnel. ALOTS operators, aircraft flight crew, and aircraft maintenance personnel are excluded for the obvious reasons, such as no position being manned and capability already established.

4.3 IMPLEMENTATION

The complete A/RIA Personnel Subsystem Program Plan was presented in the System Proposal Report 52929. The details of the Personnel Subsystem Test and Evaluation (PSTE) were outlined in Report No. TU-28325, as the

annex, in compliance with Data Item Q-7-28.0. TU-28325 outlines the responsibilities of the PSTE team, and procedures to be used for the collection of personnel subsystem data during Category II testing, and its evaluation and presentation.

Category II Personnel Subsystem test and evaluation were performed concurrently with Category II System testing to verify that the requirements specified in Section 3 of the System Specification have been satisfied.

4.3.1 Operational Proficiency

4.3.1.1 Phase I – Preliminary Evaluation

The purpose of this evaluation was to establish the baselines for the PSTE, by BxR personnel through observation by PSTE observers, for later evaluation of Air Force operational personnel. A minimum of one (1) successful flight test mission was required, observed by four (4) PS Observers, or four missions by one (1) PS Observer. In establishing the baselines for this phase, three (3) PS Observers were utilized at various times during eleven (11) flights. Each PMEE position was observed for use of checklist procedures, A/RIA Flight Test PMEE Flight Cards and Human Engineering/Life Support design criteria. Each flight observed was documented by the respective PS Observer, and the resulting documentation was then consolidated into one report for that individual flight. Distribution was made to those offices concerned for information and/or necessary action.

Phase I was considered complete when each PMEE position operator demonstrated successful test mission performance in accordance with the checklist and flight cards. From this preliminary evaluation the procedures were established for the Phase II and Phase III evaluations.

Data acquired during this phase was gleaned from eleven (11) flights totaling 61:30 flight hours, two (2) BxR PMEE crews, and 121:00 flight hours of observations by three (3) PS Observers.

4.3.1.2 Phase II – Transitional Evaluation

The objective of this phase was to evaluate the indoctrination and transition training of the Air Force operational personnel into the A/RIA PMEE System. This phase required a minimum of one (1) successful flight mission demonstration for each Air Force operator per position. However, the Air Force personnel present for the transition training elected to eliminate in its entirety the Personnel Subsystem Test and Evaluation Phase II of the Category II Test.

4.3.1.3 Operational Evaluation

This phase required the demonstration of the capability of a complete Air Force PMEE crew to operate the system through a minimum of one successful operational flight mission (actual or simulated). Data were acquired during three flights totaling 16:30 hours with 22:00 hours of PS observation of two (2) Air Force PMEE crews. The baselines established in Phase I

were employed to evaluate the performance of the Air Force PMEE crews through the use of checklists, flight cards, procedures and measure of success.

On 16 February 1967, Capt. Aiken and Crew demonstrated that a complete Air Force PMEE crew can operate the 435A through a successful simulated operational flight mission. This event terminated Phase III of the Category II PSTE.

Fourteen (14) demonstration flights by four different crews (two BxR and two Air Force) provided the data for evaluating the proficiency of operational personnel.

4.3.2 Maintenance Proficiency

Maintenance functions were performed during, and in support of, Category II Testing on an as-failed basis to demonstrate maintenance personnel proficiency. Data were gathered on pre-flight, checkout and maintenance activities from 9 January 1967 through 10 February 1967. However, insufficient data were obtained to enable PS Engineering to certify that Air Force personnel proficiency was adequate for all troubleshooting and repair. The reason that the data are insufficient was that not enough failures occurred during the Air Force personnel familiarization [illegible] at Douglas-Tulsa. It is recommended that the demonstration continu[illegible]g Category III Testing.

It might be pointed out that the Category II procedures specified the Category II testing would be a joint effort between Douglas, Bendix, and the Customer. With the exception of coordination efforts of one Air Force Officer, there was no Air Force Personnel Subsystem Engineering representation at this facility during Category II testing.

Excellent information was obtained from the Air Force Operations/Maintenance personnel during the familiarization tour. However, only four of the PSTE checklists furnished them were completed and returned.

The following is a recap of Category II Personnel Subsystem Verification Demonstrations and data acquired:

Demonstrations

14 Flights - 78 flight hours - 1, 2, or 3 Observer/Evaluators - 143 hours observation.

First Flight - 7 December 1966 - Last Flight - 6 February 1967.

Phase I — 11 flights — 61:30 flight hours - two BxR Crews - 121 hours observation.

Phase II — None.

Phase III — 3 flights - 16:30 flight hours - two Air Force Crews - 22 hours observation.

Pre-Flight, Setup, Checkout and Maintenance - 9 January through 10 February 1967.

7 PPCL's (Consisting of abbreviated checklists, flight cards, and pre-flight and checkout procedures).

60 Reports of Interview (BxR and Air Force Operations/Maintenance Personnel).

25 Observer/Evaluator Reports.

14 Flight Test Requests.

14 Flight Test Reports.

6 PSTE Checklists (BxR personnel).

6 Maintainability Checklists (BxR personnel).

4 PSTE Checklists (Air Force personnel).

4 Maintainability Checklists (Air Force personnel).

1 Air Force Crew Qualification Statement (from BxR).

4.4 RESULTS

4.4.1 Operations

The Category II PSTE effort was concerned primarily with verifying that the 435A System can be operated, maintained, controlled and supported by U.S. Air Force personnel.

Operational proficiency of the system was adequately demonstrated by a complete Air Force PMEE crew on 16 February 1967, which included pre-mission setup, pre-flight and flight.

4.4.2 Maintenance

As previously pointed out in paragraph 4.3.2, insufficient data were gathered pertaining to maintenance proficiency of AF PMEE crews, due to the short indoctrination period and lack of system failures.

4.4.3 Manuals

During the AF PMEE crew familiarization tour at Douglas-Tulsa, 27 "Reports of Interview" with Air Force "Operational" and "Maintenance" personnel were conducted. A cursory analysis of the comments revealed that the setup and checkout procedures contained in the BxR published manuals were not adequate and did not meet the requirements of AFSCM 310-1/AFLCM 310-1 Data Item No. U-H-56.1, "Range Instrumentation, Operation and Maintenance Manuals." Since this was known prior to the operational crew's integration start date, Air Force management personnel from ETR agreed to use the field test procedures, which were developed locally during and for Category II test operations by BxR personnel, in lieu of manuals. This agreement was only a stop-gap expedient for Category II operations, i.e., learning how to operate the PMEE.

Subsequent to the Category II operations the field test set-up and checkout procedures were updated, corrected and/or included in Section III of applicable manuals prior to their final publication and delivery.

4.4.4 Equipment Discrepancies

Forty-five "Reports of Interview," prepared by Douglas PSTE Observer/Evaluators for ground operations and maintenance functions, revealed equipment discrepancies and problem areas. The majority of the comments were personal opinions; other comments pertained to commercial "off-the-shelf" equipment where no corrective action could be taken under the present contractual requirements. Representative samples of discrepancies and corrective actions are:

4.4.4.1 Inadequate Cabin Air Temperature Control

PMEE compartment temperature surveys conducted during the Category II Test Program indicated excessive temperature differences between head and foot levels at the forward PMEE Operator positions and a generally higher temperature in the aft test area. Installation of the production interior partitions and carpet installations will improve the temperature distribution. Design changes have been made to the cabin temperature sensor installation for improved regulation. Adjustment settings of the air conditioning air outlet diffusers as developed on the flight test program have been incorporated into the engineering drawings and aircraft handbook rigging procedures.

4.4.4.2 OA-20 Overheat Indications

OA-20 overheat indications are caused by inadequate ventilation of the OA-20 cabinet which results in heat air exhausted from the units in the cabinet being re-circulated back to the individual black box blower inlets instead of being discharged through the back web of the cabinet. An air deflector was fabricated and installed at the cool air duct outlet to deflect cool air up and across the front of the OA-20.

4.4.4.3 Servo Amplifier Power Supply

The Servo Amplifier Power Supply is all hard-wired to the circuit boards with no connectors.

The PC boards in the Servo Amplifier Power Supply Drawer are not meant to be directly interchangeable because of the number of "SAT" (Select at Test) components. This was approved by DR No. 81.

4.4.4.4 Main Circuit Boards (Antenna Control Console)

The two Main Circuit Boards in the Antenna Control Console are hard-wired in the chassis with no connectors.

The decision to hard-wire the PC boards rather than use connectors was made in consideration of the fact that the impedances are very high and the circuits

susceptive to pick-up. The use of connectors would be highly unsatisfactory from an engineering standpoint, due to the critical nature of the circuitry. DR No. 81, defining this subject, was approved by ESD.

4.4.4.5 Interphone Facility

The System Analyst does not have the facility to talk on the interphone from any position.

"Listen only" interphone capability at the PMEE operating positions for the system analyst was added by PSC #17. This design was approved at the CDR.

4.4.4.6 Voice Annotation

The present setup makes voice annotation of the tape recorder very difficult. This was a compatibility change. The Record Operator was provided a mode selector switch to allow him to annotate the tapes. Sidetone of all operators was changed from a -20 dB to a -6 dB to allow recording of each operator's voice as desired by patching. These changes were resolved by incorporation of ECP 0047.

4.4.4.7 Additional Equipment

Additional equipment appears to be needed in the recorder position, e.g., ECP 55 plus a degausser.

The additional test equipment referred to in ECP 55 is presently under study. The budgetary estimate for the proposed change is currently being prepared. This proposed change will provide all of the test equipment necessary to align and troubleshoot all of the equipment in the record group. ECP 55 submitted 5 May 1967.

4.4.4.8 Antenna Control Console Interchangeability

The antenna control console and the servo amplifier power supply are not interchangeable from one aircraft to another unless moved as a pair.

Interchangeability tests were conducted on Systems 1, 2, and 3 at Tulsa on 24 April 1967. Test results were satisfactory.

4.4.4.9 Interlock and Auto Safety Systems

No interlock or auto safety system is known to exist that would prevent power from being applied to the antenna while a man is working in the radome.

Adequate safety procedures are incorporated in the aircraft handbooks to eliminate any safety hazard associated with the Radome Antenna. The procedures include (a) warning signs on the radome, (b) streamers on circuit breakers at Antenna Console, and (c) communication facilities between radome area and console position.

4.4.4.10 Servo Power Amplifier Power Supply

The fuses have been removed from the servo amplifier power supply. The only safety device left is the circuit breakers which have proved not to be satisfactory.

Circuit breakers are being installed to provide adequate protection to the system.

4.5 RECOMMENDED CATEGORY III TEST OBJECTIVES

4.5.1 Operational Control Procedures

Operational Control Procedures are required to verify that procedures used to control personnel during operation and maintenance (scheduled and unscheduled), or of the A/RIA System are adequate. Tests include:

a. Maintenance Procedures Adequacy.

b. Quality Control Adequacy.

c. Maintenance Records Adequacy.

d. Operational Control by Personnel.

4.5.2 Organizational Maintenance Effectiveness

Organizational maintenance effectiveness is required to verify that the effectiveness of the assigned Flightline Organizational area, in support of the A/RIA System, is adequate.

4.5.3 Training and Training Equipment

Adequate support of the A/RIA System by the training and training equipment (AAE) provided by ATC will be verified.

SECTION V

PERSONNEL/EQUIPMENT DATA (PED)

5.1 OBJECTIVES

The first PSS concern was the establishment of a PED File. The A/RIA PED was established in accordance with AFR 30-8 to be a centrally located and maintained body of analytical data, in the form of task and equipment information, and to fulfill the technical requirements of AFSCM/AFLCM 310-1. Organization and maintenance of the file has been in accordance with criteria outlined in AFSCM 80-3. All available data generated during the course of A/RIA System development which will help to describe interfaces where human behavior can affect system performance has been collected in order to:

a. Verify that equipment design is adequate for safe and efficient use by the operator and maintenance personnel.

b. Verify personnel and manning requirements and allocations (QQPRI, Training, etc.).

c. Validate technical orders and manuals.

d. Develop proficiency measures for Category II/III personnel performance testing.

During the "Contract (Program) Definition Phase" the PED file was utilized for a variety of documentation and correspondence that passed through the A/RIA Program Office. Elimination of all sundry material alien to PED criteria (AFR 30-8 and AFSCM 80-3) was accomplished.

5.2 IMPLEMENTATION

The re-vamped PED was organized to support the PS functional areas — particularly the objectives of Category I and II PSTE. The file was divided into six categories:

5.2.1 Category A

Applicable A/RIA Douglas/Bendix Reports (52900 Series). All reports generated during the A/RIA Program Definition Phase, up to and including 23 August 1965, were reviewed and evaluated. Those that were found valuable as program background material, PS development material, and program plans were used toward completion of PSTE Annex objectives and AFSCM/AFLCM 310-1 reporting requirements. All are a part of PED (Data Items 001 through 043).

5.2.2 Category B

Bendix Radio Technical Notes, Drawing and Tradeoff studies. All available Bendix Technical Notes and Tradeoff studies, generated during the Program Definition Phase, were reviewed and evaluated. Those providing general program information, rationale for PMEE system configuration, and subject

material for Douglas (PS) task, timeline, and link analyses were made a part of PED (Data Items 060 through 143).

5.2.3 Category C

Douglas/Bendix FFBD/RAS. FFBD/RAS development by both Douglas and Bendix Systems Engineering were updated during the A/RIA acquisition phase to the time of CDR. Those generated prior to 23 August 1965, have been extracted from Douglas/Bendix A/RIA Reports 52902 and 52903 and made a part of PED (Data Items 200 to 290). Enlarged copies of the same have been collected and are also a part of PED. Note: The FFBD/RAS was not a contractual data item for this program.

5.2.4 Category D

PSTE Data (TU-28325). PED was organized to support the PSTE objectives of A/RIA Category I and II testing. To systematically collect, organize, and assimilate data, Category D has to be subdivided to coincide with PSTE Annex (25 March 1966) Category I and II test planning. Each PSTE test plan and procedure has been made a data item, into which support information is incorporated as it is generated.

5.2.5 Category E

Human Engineering/Life Support Data. Personnel Subsystem has investigated a number of A/RIA critical areas not in direct support of any particular PSTE objective. These human engineering endeavors have each been assigned a Category E data item number.

5.2.6 Category F

Personnel Subsystem Group File (PS Disciplines and/or PED Supporting Data). In addition to the formal PED file noted and described above, pertinent documentation used in the support of overall PS activity has been collected and maintained.

The Personnel Subsystem Group File contains documentation in the way of specifications, Air Force Manuals, etc., used to support the overall PS effort.

As outlined in the Douglas "A/RIA Standard Practice Memorandum 2412," use of PED material by both the PS Group, and general Engineering was a documented procedure.

5.3 PRODUCTS

5.3.1 ALOTS Installation

On 11 April 1966, an investigation into the time requirement for exchange of the ALOTS System between EC-135N aircraft was initiated. A/RIA Part I CEI CP100007A (ALOTS Provisions for A/RIA), paragraph 3.1.2.2, indicated a time limit of 48 hours for exchange of the system between A/RIA aircraft, exclusive of the M.T.S. life support panel and sighting dome.

Using the ALOTS Preliminary Instruction Manuals, prepared by Nortronics Corporation (Volumes 1 through 4), a task and timeline analysis was done. Installation time began when relieving aircraft cargo door was removed, and ended when receiving aircraft was ready for ALOTS pre-flight operational checks.

The task analysis indicated that physical installation and qualification checkout required 31 steps. Resultant installation and qualification checkout time was estimated at 28 hours and 15 minutes. Fifty percent of that figure was added for support equipment setup and removal. The resultant total figure was 42 hours.

In support of the above figures, each installation task requiring more than 15 minutes was further examined using a Task Analysis Worksheet. Defined were job operation title, task location, personnel required, task description, techniques to be used, minimum performance standards, probable error factors, consequences of deviations from procedures, specific knowledge and skill requirements, safety precautions, and training requirements.

The 48-hour remove and replace requirement is a part of A/RIA CEI CP100007A (paragraph 3.1.2.2). Time required for ALOTS operational change is 42 hours, which was arrived at through technical analysis.

5.3.2 A/RIA PMEE Mission Critical Operational Period

In the middle of June, an analysis of PMEE Operator activity during the 12-minute critical portion of the A/RIA Mission was made.

Using Douglas/Bendix Reports Nos. 52902 and 52903, along with Bendix Reports Nos. 1869T1, 1869T7, and 1869T8, all A/RIA PDP documents, a FFBD was developed covering the 12-minute critical period.

Resulting from this FFBD, six PMEE Operator task lists were prepared. The FFBD was used until receipt of hardware and operating manuals prepared by BxR.

All data collected, and in an updated state as of 1 September 1966, is a part of the PED File (Data Item 440).

5.3.3 A/RIA Emergency Escape Procedures

Task, timeline, and link analyses were done to investigate and establish escape procedures for abandoning the EC-135N during various emergency configurations. Included were ditching; immediate, high- and low-altitude bailout; and crash landing.

Analysis was done to determine possible positioning of crew members and procedures for ditching in the EC-135N aircraft. Considered was an onboard complement of 23 personnel, including air crew members, A/RIA PMEE Operators, ALOTS Operators, and passenger. Also considered was the unique relationship between the air crew and other onboard personnel. Finally considered was the structural mounting of seating and PMEE in both occupied and unoccupied areas.

Positioning of all personnel during a ditching situation was based on subsystem configuration, location of escape hatches, and location of emergency equipment.

Due to overall on-board crew composition, responsibilities assigned to air crew members were designed to optimize the chance for successful evacuation of all personnel during a ditching operation.

Analysis was done to investigate and establish procedures for bailout from the EC-135N under four different conditions: immediate, high altitude, low altitude, and over water. Responsibilities during all four different conditions were based on air crew familiarity with procedures, location of escape hatches and emergency escape ropes and location of necessary emergency equipment.

Procedures resulted from onboard personnel positioning during airborne conditions, location of emergency equipment, and access to emergency escape ropes and hatches.

Analysis was done to investigate and establish personnel procedures to be used during EC-135N aircraft let-down with nose gear and/or main gear retracted.

Resultant responsibility for initiation of crew alert and aircraft let-down was vested with the on-duty air crew. Responsibility for distribution of emergency equipment, removal of escape hatches, and supervision of evacuation was vested with off-duty air crew members.

On 7 July 1966, Emergency Escape Procedures were prepared as inputs to Section 3 of the A/RIA Flight Manual, 1C-135(E)N-1. Review of the preliminary draft of 1C-135(E)N-1 (20 September 1966) indicates that substantial portions of the (PS) submittal was incorporated in sections of the above manuscript.

All data generated, as noted are a part of the PED File (Data Item 430).

5.3.4 A/RIA Nose Radome/Fairing Component Remove and Replace

Task, timeline, and link analyses were done to investigate, remove, and replace the UHF/VHF Antenna Vertical Reference Gyro, the AS653A/APN APN-59 Search Radar Antenna, and radome fairing modules.

Analysis of remove and replacement of the Vertical Reference Gyro considered component location, power shutdown, radome accessibility, personnel requirements, and job aids. Not considered were component troubleshooting or gyro realignment inside the antenna mount assembly.

Resultant remove/replace estimate as a result of this analysis was 88 minutes and 30 seconds.

A task and timeline analysis was done to investigate remove and replace of the AS653A/APN-59 Search Radar Antenna located in the nose radome of the A/RIA EC-135N aircraft. Considered was component location, radome accessibility, personnel requirements, and job aids. Remove and replace

procedures were bas on T. O. 1C-135A-2-11-1, visual inspection of the radome area (A/RIA Aircraft No. 1), AS653A/APN-59 Search Radar Assembly, and Bendix Drawing No. 2004695.

SS100000, paragraph 3. 1. 1. 3. 5, indicates that 203 aircraft maintenance personnel will be assigned to the A/RIA aircraft. Because the APN-59 antenna is part of the basic aircraft, its maintainability is the responsibility of the above personnel (AFSC's have not been assigned).

The analysis indicated that approximately 21 minutes will be needed to remove the antenna. If the stabilization data generator is also removed, overall remove time becomes approximately 25 minutes. Total remove/replace time for the antenna is approximately 51 minutes. Remove/replace time for both antenna and generator is approximately 59 minutes.

A task and timeline analysis was done to investigate remove and replace of the antenna assembly modules located in the nose radome fairing. Considered were component location, radome fairing accessibility, personnel requirements and job aids. The analysis was based on physical inspection/measurement of the fairing interior (A/RIA Aircraft No. 1).

Considered in the analysis were two TWT Amplifier Assemblies OA50-4 and -15, each weighing approximately 60 pounds, the VHF Channel Assembly OA50-2, weighing approximately 35 pounds, and the VHF Voice Tx/Rx Assembly OA50-3, weighing approximately 30 pounds.

The remove and replace analysis indicated that removal of OA50-2 or -3 will take about 9 minutes. Removal and replacement requires about 20 minutes. Removal of OA50-14 or -15 will take about 16 minutes. Removal and replacement about 35 minutes.

A/RIA UHF/VHF Antenna Vertical Reference Gyro remove and replace — Douglas Drawing No. A100211 deviations:

Paragraph 8. 6. 3 Accessibility — Units shall not be placed in recesses, behind or under stress members, floor boards, seats, boards, hoses, or other items which may be difficult to remove.

The vertical reference gyro is encased in the antenna pedestal. Antenna cabling/wiring makes access to pedestal assembly interior difficult. Units surrounding the gyro inside the pedestal assembly make removal of gyro impossible without also removing its mounting platform.

AS653A/APN-59 Search Radar Antenna remove and replace — Douglas Drawing No. A100211 deviations:

Paragraph 8.5.2 Weight

a. Lifting by one man — Whenever feasible, equipment shall be modularized so that the weight of each removable unit does not exceed 45 pounds.

   MIL-STD-803A-1, paragraph 9.2.4 Unusual Positions -

   Minimum vertical work space clearance - 42 inches.

   Minimum crawl space vertical clearance - 17 inches.

   Vertical work space clearance varies from 16-1/2 inches at the nose radome access hatch to 37 inches at Station 178.

   Vertical clearance at nose radome access hatch is 16-1/2 inches.

APPENDIX VIII

SYSTEM SAFETY ENGINEERING SUMMARY REPORT

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LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

AFB	Air Force Base
AF	Air Force
AFTO 22	AF Tech. Order Change Form 22
A-LOTS	Airborne Lightweight Optics Tracking System
A/RIA	Apollo Range Instrumented Aircraft
BxR	Bendix
CEI	Contractor End Item
C.G.	Center of Gravity
DACo	Douglas
ERI	Engineering Review Item
FACI	First Article Configuration Inspection
PMEE	Prime Mission Electronic Equipment
SSCL	System Safety Checklist
SSE	System Safety Engineering
SSEP	System Safety Engineer Plan
T.O.	Technical Order
TWA	Trailing Wire Antenna
UHF	Ultra High Frequency
VHF	Very High Frequency

SECTION 1

INTRODUCTION

This Final System Safety Engineering Summary Report is written in conjunction with MIL-S-38130 and supports all system safety activities incumbent with the A/RIA (Apollo Range Instrumented Aircraft) Program.

The System Safety Engineering Program Plan, Douglas Report No. 52932, was written in the program definition phase of the A/RIA project; it too was governed and dictated by the precepts of MIL-S-38130.

All of the various efforts, forms, coordinative activities, reports, monitor functions, etc., which are called for in the SSEP (Report No. 52932), and were carried to successful conclusion contributory to A/RIA system safety, are described in detail herein.

The System Safety Engineering Documentation File (in two volumes), the Norton AFB Safety Wire File, and the SSE Correspondence File constitute the back-up information used in the compilation of this report. These archives are available for customer investigation at any time.

SECTION II

SUMMARY

The A/RIA System design included major modification to a C-135 type aircraft. Considerations involving safety which were investigated during A/RIA design, test and development, fell into the following categories:

1. Aircraft Modification
   a. Generator modification
   b. Aerodynamic changes to the airframe, addition of radome nose, fairing, TWA nest, and wing tip antenna
   c. Gross weight and center of gravity changes affecting the airframe
   d. Modification of the environmental control system
   e. Trailing wire antenna design and installation
   f. Emergency egress and variations in T.O. escape routes peculiar to A/RIA
2. PMEE Installation
   a. Rack mounting
   b. Cooling equipment and ducting
   c. Operator positions
   d. PMEE Itself (BxR)
3. Procedural media affected by safety factors.

The flight characteristics of the C-135 were not, effectively or adversely, altered by the modification of the aircraft to the A/RIA configuration. See Category I Aero-Structural Flight Test Report (ESD-TR-67-293) for specific details.

Results of tests conducted showed that the system electrical load was not significantly greater than for the basic C-135 vehicle. All future growth potential may easily and safely be handled with the inclusion of the additional generator source on the No. 4 Engine.

Various additions and deletions made to the airframe do not adversely affect gross weight and center of gravity. Lateral, directional, and longitudinal trimability do not differ perceptibly from basic C-135 aircraft. Fuel

management for climb, cruise, etc., varies only slightly from standard C-135 aircraft, with the c.g. limits shifting slightly aft. The A-LOTS configuration showed some differences on lateral/directional dynamic stability from the standard A/RIA. Performance of the A-LOTS-configured A/RIA was satisfactory in all respects.

Installed PMEE and equipment racks have been designed to withstand acceleration shocks at least equal to those expected in other portions of the airframe during ditching. Operators' takeoff seat positions are designed to withstand accelerations associated with ditching. New bailout and emergency egress procedures have been developed for the A/RIA cabin arrangement, and should make this configuration comparable favorably, from an escape standpoint, with other aircraft of the C-135 series. Electrical shock has been effectively precluded from the A/RIA PMEE design.

SECTION III

TEST AND EVALUATION

3.1 GENERAL

During Category II the specific safety responsibilities included, but were not limited to all of the following:

a. Coordination and review of Failure Analyses from Design Sections

b. Review of System Safety Checklists from all safety sources

c. Review and classification of test data received from all sources

d. Monitoring of component, subsystem, and system tests affecting safety, which were conducted by the Contractor

e. Interviewing of AF/Subcontractor personnel, questioning for potential/actual safety hazards; especially during set-up and check-out of the PMEE

f. Processing of Hazard Reports received

g. Creating of Contractor Safety Bulletins, where required, to alleviate Douglas safety problems prior to -1 T.O. revision and issuance

h. Modifying Technical Orders (Safety Supplements)

i. Monitoring of and passing on of information received in Norton AFB Safety Wires affecting C/KC-135 types of aircraft.

A pictorial summary of System Safety activities is presented in Figure VIII-1, "A/RIA System Safety Engineering Schedule."

3.2 SPECIFIC

3.2.1 Coordination of Failure Analyses

During Category II flight test, the failure analyses performed in-house were coordinated, classified and filed. The Failure Analysis form (including modes and effects) was utilized as an adjunctive to trouble-shooting or trouble analysis. Approximately 40 of these sheets were prepared in support of this effort.

Results of failure prediction analyses figured heavily in rewriting portions of Technical Orders pertaining to trouble analysis (trouble-shooting procedures). Complete failure analysis forms were substituted, almost intact, into appropriate sections of the T.O. dealing with environmental control, electrical power problems, and No. 4 Engine Generator/ Alternator.

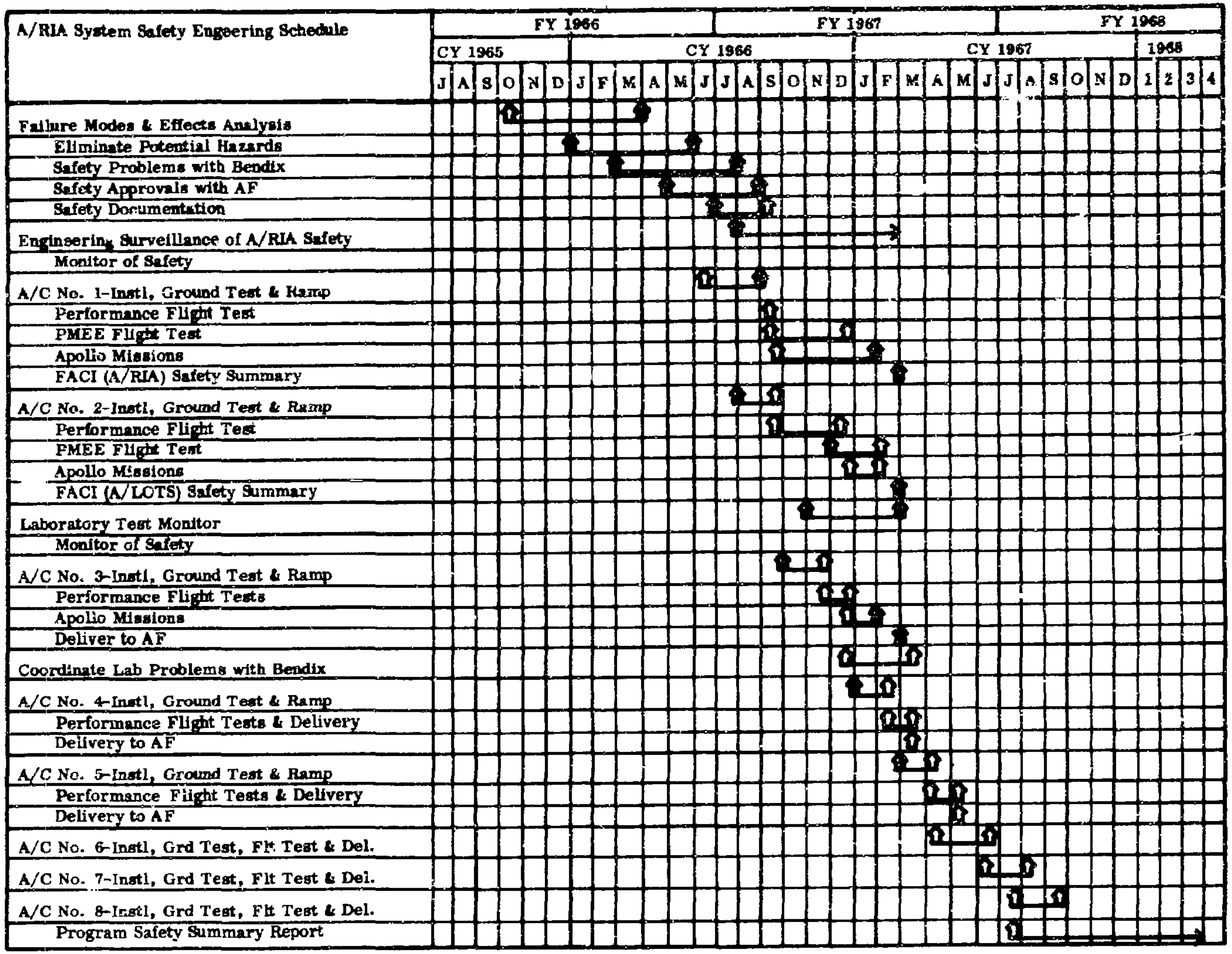

FIGURE VIII-1. SYSTEMS SAFETY ENGINEERING SCHEDULE

In certain cases, especially where PMEE was concerned, safety personnel coordinated directly with the Publications Section in developing safety procedural media.

3.2.2 Processing of System Safety Checklists

The System Safety Checklist form was prepared in all necessary areas. This checklist is comprised of 42 questions having safety impetus. These questions are asked by designers of every component within the A/RIA System where a potential hazard might have existed. The questions are worded so that a "Yes" or "No" will answer them. "No" answers to checklist questions reflect a safe condition for the component or part. Investigation is not continued on parts giving up all "No" answers. "Yes" answers to questions show that the part is potentially hazardous and that further investigation is required in order to arrive at a safe solution to the problem posed by the "Yes" answer. Over 40 sets of seven pages each of SSCL's were prepared.

A System Safety Worksheet was always processed for each checklist question showing a "Yes" (unsafe) answer.

3.2.3 System Safety Worksheets

A System Safety Worksheet was prepared in response to each "Yes" answer to an SSCL question. In excess of 200 System Safety Worksheets were prepared in support of the SSCL's written against A/RIA PMEE components.

Examples of specific problems resolved by Worksheets during Category II of the A/RIA Program are listed as follows:

a. Patch panel problems concerning electrical shock were alleviated by the utilization of protective warning on the panels themselves and by the inclusion of appropriate entries in the T.O.

b. Several of the PMEE Drawer Units were too heavy for one man to remove and replace, especially in the cramped OA-19/OA-20 aisleway. Weights were marked clearly on all oversized (overweight) components and appropriate entries were made in the T.O.'s.

c. It was possible for an antenna control console operator to inadvertently trip either the Azimuth or Elevation Control of the UHF scanner while maintenance personnel worked in the radome. Incorporation of warning streamers, and coordinative entries in T.O.'s affecting maintenance/operations personnel and their usage of the equipment, reduces this possibility.

d. The UHF dish emitted rays in an increased arc to that of the VHF antenna; because of this the safety hazard area was increased from a line 10° clockwise and counterclockwise of a line normal to Station 278 to a line 45° clockwise and counterclockwise of the same reference plane.

e. Certain high voltage and high frequency areas were accessible to operational and maintenance personnel. These areas have been given protective covers and these covers have been clearly labeled; additionally, appropriate entries have been made in the pertinent T.O. paragraphs.

3.2.4 Hazard Reporting

MIL-S-38130 describes safety hazards in a precise manner. There are four classes of hazards associated with system safety. They are respectively, from the least hazardous to the most hazardous, Class I, safe; Class II, marginal; Class III, critical; and Class IV, catastrophic.

The contractor has acted to remove all Class IV hazards, and reduce Class III's and II's to the safe (Class I) classification. This result has been effected through the use of a closely coordinated hazard reporting program. Approximately 30 hazards were reported during the A/RIA Program.

Significant hazards which have been reported and corrected during the A/RIA Program are listed as follows:

a. PMEE cooling ducting in aisle for OA-8/OA-9 is positioned so that when the two individuals involved assume their ditching positions located there, said ducting strikes them in the back of the heads. To alleviate the possibility of serious injury at these positions during ditching, backboards were designed and installed.

b. The interface between BxR and Douglas male/female connector plugs was unsafe (did not supply proper grounding). Consequently, adapters were designed and are now in use.

c. Magnesium ducts were being used on the No. 4 Engine Panel in a location planned for exit gases (very high temperature) accompanying a cartridge start. All stainless ducting has been substituted in this position.

d. The marking of the Emergency Annunciator Panel was inconsistent. Originally letters other than "X" had been used to mark this panel. Now all emergency annunciator panels are marked the same, with the letter "X."

e. A potential hazard exists for the A-LOTS "High-Chair" operator in the event of explosive decompression. It is possible for an individual occupying this position, and without his seat belt or shoulder harness in place, to be drawn out the sighting bubble hole.

3.2.5 Test Monitoring

The program was monitored during ground and flight tests having any potential safety significance. Component and subsystem tests conducted on a laboratory basis, and significant to the A/RIA safety effort were:

a. Tensile strength tests conducted on the Trailing Wire Antenna. Determination of the particular wire to be ultimately used in the TWA design was made from these tests.

b. Environmental tests conducted on the TWA controls.

c. Strength tests run on the A/RIA radome nose.

d. Electrical load tests and analysis conducted on the (newly designed) No. 4 Engine Alternator/Generator.

Tests monitored on major subsystems and/or the total A/RIA System are as follows:

a. Pressurization and leakage tests conducted on the pressurized cabin.

b. Landing gear swing tests with the aircraft jacked.

c. PMEE tests, including cooling (especially ground cooling), of the equipment.

d. Ground check-out of the PMEE, including pre-flight setup operations.

Data from flight test were reviewed, analyzed, and filed, and portions of it having safety significance now comprise a section of the System Safety Documentation File. From a safety standpoint the flight characteristics, electrical loads, ditching and emergency egress problems entailed in the new design do not differ adversely from those of basic C-135 aircraft.

3.2.6 Design Coordination

During Category II, System Safety Engineering took an active part in Contractor End Item (CEI) and Engineering Review Item (ERI) meetings. The safety function also was present (on a standby basis) for all locally presented FACI (First Article Configuration Inspection) meetings.

Although most of the design coordination with the various Engineering Design Sections (and with Safety counterparts at BxR) was conducted during Category I, a significant portion, especially where feedback from the field figured heavily in decisions made, carried over into Category II. Design feedback liaison with the customer was heaviest during Catetory II testing, after AF personnel had had the opportunity to more fully evaluate equipment under operational conditions.

SECTION IV

RESULTS

As a result of System Safety action taken in the form of design coordination, participation in design reviews, monitoring of tests on components, subsystem, and systems, the A/RIA vehicle is as safe as a basic C-135. In addition, much of the analysis work performed, i.e., failure prediction analysis, system safety checklist and worksheet analysis, and hazard reporting and analysis located and corrected mistakes (often) previously unnoticed in the basic C-135 design and/or pertinent Technical Orders.

Specific examples of potential safety problems in the basic C-135 which were closely monitored and frequently corrected by the SSE are:

a. Lack of supports for the cargo door to hold it in the open position

b. Cracks located in various parts of the airframe especially,

   (1) Vertical Fin attach fittings

   (2) Landing Gear (main gear mainly)

   (3) Hydraulic Leak Problems (cracked hydraulic cylinders)

c. The use of magnesium flanges for a cartridge start exhaust duct on the No. 4 Nacelle Inboard Panel

d. Inability, on frequent occasions, to assure a down lock on the nose landing gear

e. Serious problems involved in removing the spoiler from the crew entry door during maintenance activities

f. Various and sundry problems originating in the CSD Gearbox and related equipments

   (1) Generator will not stay on the line

   (2) Stripping of gears

   (3) Loss of lubricant/eventual destruction of the CSD.

SECTION V

RECOMMENDATIONS

Specific recommendations concerning System Safety for the A/RIA Program are as follows:

a. Cargo doors should be supplied with braces to hold them in the up (open) position.

b. The T. O. should be altered t effect this change in maintenance procedures. (AFTO Form 22 has been submitted.)

c. On ALOTS-equipped machines, special procedures will be developed. The "high chair" operator should wear his safety belt at all times, in order to preclude a hazardous situation in the event of explosive decompression.

APPENDIX IX

A/RIA ALOTS

COMPATIBILITY

FINAL REPORT

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1.0 INTRODUCTION

The general specification for the Apollo/Range Instrumented Aircraft (A/RIA), SS100000, established the requirement that four of the eight A/RIA be equipped with the Airborne Lightweight Optics System (ALOTS). The ALOTS was supplied to the contractor as an operational system for incorporation into the A/RIA.

ALOTS is used for detailed documentary and engineering sequential photographic coverage of missiles and space vehicles during early launch, passage through high dynamic pressure portions, staging and separation, re-entry and recovery. During the PDP, the compatibility between ALOTS and A/RIA's Prime Mission Electronics Equipment (PMEE) was investigated. Concurrent use was shown to be feasible (Ref. DAC Report No. 52940). It was found to be technically possible to fly the aircraft so that both the PMEE and ALOTS data acquisition systems could be brought to bear on a given target when it was within the range of both data systems.

The required compatibility testing was accomplished as a part of the Category II Test Program on A/RIA AFSN 61-327 out of the contractor's Tulsa, Oklahoma facility. Ground tests were run on 22 May 1967, the Flight Test (Flight No. 29) was made on 25 May 1967. The test procedures were described in Supplement No. 1 to DAC 56171 (A/RIA Category II Test Program).

This final report describes the compatibility between ALOTS and A/RIA.

2.0 SUMMARY

The general objective of the flight test program was to determine to what extent the ALOTS can be simultaneously used with the A/RIA's PMEE. Since ALOTS was supplied to the contractor as an operational system for incorporation into the A/RIA it was not tested per se. It was established that it was working properly prior to the start of compatibility testing.

Specifically, the testing established A/RIA ALOTS compatibility electromagnetically, environmentally, and operationally.

All of the flight test objectives were met successfully. With ALOTS operating, PMEE acquisition and tracking was successfully accomplished at P-Band, L-Band, and S-Band frequencies; telemetry data were recorded; teletype was used; rate memory was exercised.

HF transmissions to 14 MHz caused light to heavy interference in the ALOTS video displays; however, this condition is known to have existed on the original ALOTS airplane, NKC-135, AFSN 55-3123. The ALOTS photo camera drive motor was found to interfere with ALOTS auto track. No other interference was detected.

Temperature and acoustical surveys were conducted in the cabin in the vicinity of the ALOTS equipment. Temperatures were comfortable comparable to the basic A/RIA. Noise levels were higher than specification, but also comparable to the basic A/RIA with the exception of the manual tracking station (MTS); at the MTS the levels were exceeded by as much as 30.1 dB.

The testing proved conclusively that there is a large area of overlap between ALOTS and PMEE, and in that region the systems are compatible, thus allowing simultaneous acquisition and tracking.

3.0 ALOTS CONFIGURATION

The ALOTS subsystem, supplied to Douglas by the Air Force, was modified by Nortronics for incorporation into the A/RIA system. It consists of four integrated major components:

a. Manual tracking station;

b. Control console;

c. Automatic tracking system;

d. Photographic System. (See Figure IX-1.)

Manual Tracking Station. The manual tracking station is located at fuselage station 480. The original NKC-135 ALOTS airplane had it located at fuselage station 710. The ALOTS bubble was moved forward to Station 480. This location places the astrodome and its associated equipment in the vicinity of the cargo door—thus grouping the ALOTS equipment in one area.

Control Console. The control console is located on the right side of the aircraft at Station 520. It is the central distribution point for all aircraft power input to the ALOTS. It also contains all of the controls and indicators necessary to operate the system. Among the indicators are two television monitors. One monitor displays the coarse (five and 1/2 degree) field of view, and the other, the fine (zero-degree, 39 minute) field of view. A proportional control is provided which allows manual control of the gimbal unit in the event of tracking system failure.

Some modification was effected in the ALOTS power supply so that it could operate from the airplane's power supply rather than from its own separate power source.

Automatic Tracking and Photographic (Optics) System. The automatic tracking system and the optics system are integrated into a single assembly contained in a pod, which is mounted externally on the forward cargo door. Two tracking vidicon sensors, and a recording camera, are integrally attached to a T/16, 200-inch telescope housing. The entire assembly is located on the inner gimbal of a two-axis gimbal system housed within a servo-controlled rotating turret. The system is capable of rotating plus or minus ninety degrees in elevation and plus or minus thirty degrees in azimuth from the 9 o'clock position—as referred to the aircraft.

The optical view window of the pod was not available during the scheduled tests, due to damage and Nortronics schedule for its replacement. This necessitated the use of a Nortronics aluminum panel in place of the window. This panel blocks the view of the 200-inch telescope and photographic system; however, two slots in the panel permit use of the tracking vidicon sensors. The slots restrict the field of view in azimuth to plus 20°, minus 11° in both coarse and fine tracking.

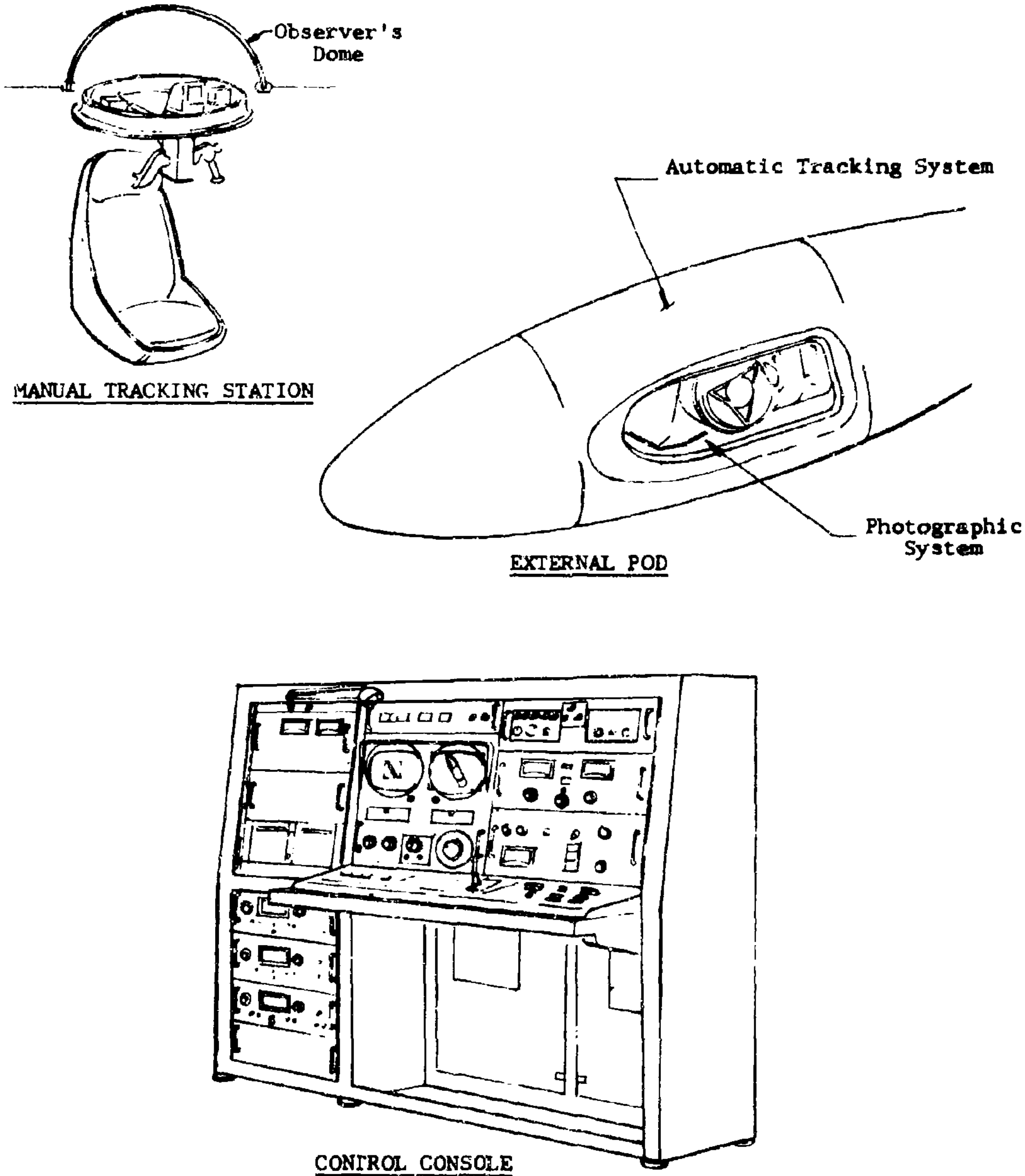

FIGURE IX-1. AIRBORNE-LIGHTWEIGHT OPTICS TRACKING SYSTEM (ALOTS)

The ALOTS pod is attached to the cargo door with one lower and two upper struts. The original C-135A cargo door was designed to be a replaceable, not an interchangeable item; therefore, four A/RIA cargo doors are modified to accept the GFAE ALOTS pod and strut assembly. The door modification consists of attachment of four GFAE bracket assemblies to the inner vertical rib structure of the standard C-135A door per DAC drawing J101523. Skin fasteners have been added to accept an aerodynamic fairing kit when the pod is not installed. The fairings do not interfere with the normal operation of the door.

4.0 TEST AND EVALUATION

4.1 GENERAL

The compatibility program consisted of both ground and flight testing as follows:

a. Ground Tests

(1) ALOTS System Operational Checks

(2) Electro-Interference Tests

b. Flight Tests

(1) PMEE System Operational Checks

(2) Electro-Interference Tests

(3) Environmental Systems Tests

(4) Operational Analysis

(5) Personnel Subsystem Testing and Evaluation (PSTE)

In addition, four other areas of compatibility testing and evaluation were completed:

c. Aircraft handling characteristics and performance with ALOTS installed on A/RIA

d. Acoustics in the vicinity of the ALOTS operations

e. Vibration environment of the ALOTS equipment

f. Aircraft electrical subsystems effects

The testing of Items c, d, and e was accomplished per Supplement No. 1 to DAC 56169 "Category I Flight Test Procedures for A/RIA ALOTS Configuration." All of the testing described therein is reported in Vol. IV of DEV-3769 (ESD-TR-67-293) "Category I Subsystems Flight Test Final Report." It is known that the ALOTS has a peak power requirement of 11 KVA (Ref. Report No. DAC 56107). The aircraft power supply system is rated at 160 KVA. During the Category I Flight Testing, each of the four 40 KVA brushless generators was loaded to a minimum of 95 percent of capacity (38 KW) with no problems. The ALOTS power requirements, together with the PMEE and aircraft system, is calculated to be approximately 98.3 KVA cruise mission load (Ref. DAC 56107). Since this is less than the total system capability of 4x38 or 152 KW no further tests were required. With one generator "out" there is a 5.1 percent excess of power while on a PMEE ALOTS mission.

Ground tests were run to verify satisfactory ALOTS operation without PMEE operating. Quality of reception was assessed and recorded by USAF ETR ALOTS specialists. In addition, ground tests were run to complete the electromagnetic compatibility (EMC) tests per Douglas Drawing A100284; specifically this was a determination of the effect of PMEE VHF voice transmission on ALOTS and the effect of ALOTS operation on the airplanes' fuel quantity indicating system and the APN-59 weather radar. These and all other EMC data are fully reported in the Category I Final Test Report, DAC 56148.

Flight testing was conducted first against the Tulsa ground station to verify that the PMEE was observed. The PMEE operator evaluators were trained Bendix Radio personnel (who had participated in the PMEE flight test program); the ALOTS operator evaluators were trained USAF ETR specialists. At the conclusion of this phase an operational evaluation was made of simultaneous utilization of the A/RIA's PMEE and ALOTS. Target for both systems was a C-121 Apollo simulator aircraft.

During the operational testing, environmental system testing was conducted including cabin air conditioning and ALOTS observer's dome defogging. A cabin sound pressure level survey was made. Throughout the entire flight test, PSTE observations were made.

4.2 TEST OPERATIONS

a. Ground Tests

The ALOTS was operated to verify satisfactory performance as follows:

(1) With ground power to the airplane, no PMEE operating, the ALOTS was turned on and operated by USAF ETR ALOTS specialists in accordance with Section III of the subsystem handbook operating procedures (see Table I) using moving vehicular traffic on the Douglas Aircraft Company Tulsa Plant flight ramp for target. Both the coarse field and fine field video monitors were viewed for modulation or interfering signals and target stability (see Figure IX-2). Operation was found to be normal; however, the ALOTS photo camera drive motors were found to interfere with auto-track.

(2) With all airplane engines running at approximately 70% N_2 RPM, no PMEE operating, all (4) generators paralleled to the SYNC BUS (per applicable paralleling procedure in T.O. 1C-135A-1), and all normal aircraft equipment turned on per Table II, the video monitors were again observed, as in (1) above, while one engine was run up to take-off power and back to idle. ALOTS operation was found to be normal but the photo camera drive motors again interfered with auto-track.

(3) Electromagnetic compatibility (EMC) testing of the ALOTS PMEE and basic airplane systems was accomplished per Douglas Aircraft Company A100284. These tests and results are fully described in the Category I Final Test Report, DAC 56148.

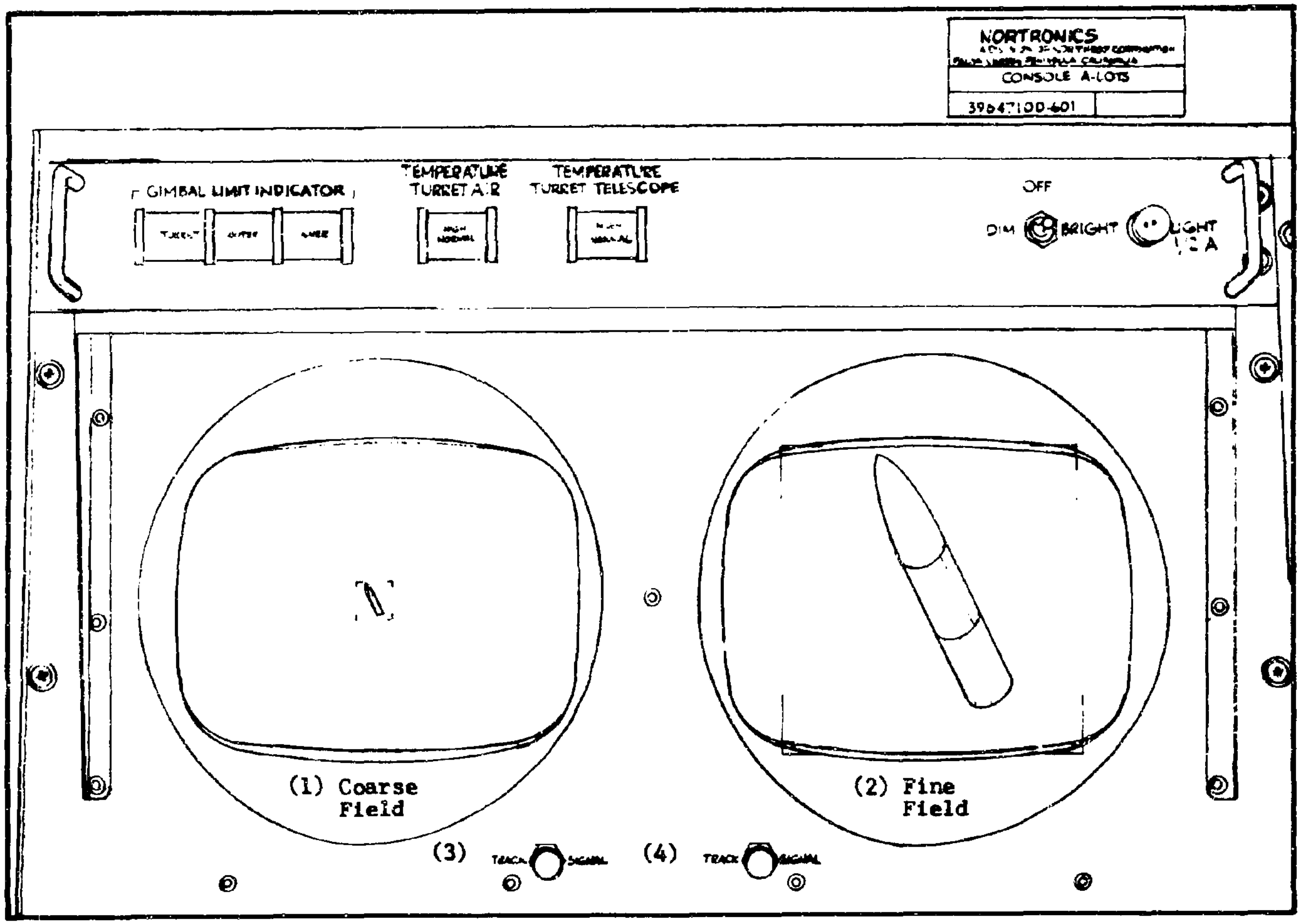

FIGURE IX-2. ALOTS VIDEO MONITORS

TABLE I

ALOTS CHECKOUT PROCEDURE

I. ALOTS TURN-ON

a.	28 VDC Circuit Breaker	ON
b.	115V 400 Power Circuit Breaker	ON
c.	115V 400 Camera Circuit Breaker	ON
*d.	Temperature Control Switch	ON
*e.	Auxiliary Heater Switch	ON
f.	MTS Track Mode	ON
g.	Monitor (Coarse) Power	ON
h.	Monitor (Fine) Power	ON
i.	T. V. Power ON-OFF	ON
j.	T. V. DC Power ON-OFF	ON
k.	MTS Blower Motor	ON
l.	MTS Flying Spot Reticle	ON
*Not normally required for ground operation		ON

II. PHOTO CAMERA CHECK

a. Press Photo Camera Switch to ON and adjust speed for 40 FPS and allow film to run for ≅ 30 sec. Turn off camera.

b. Adjust shutter from close to 120^{o} and back.

III. IRIS CONTROL

a. Press the Iris Coarse Switch to OPEN and CLOSE, indicator moves from f4. 5 to f32. Return to f11.

b. Push Iris Fine Switch until the filter cycles through the four positions. Return to No. 1

IV. PHOTO-CAMERA FOCUS

a. Adjust Focus Knob from 4. 5 NM to 00 and return.

V. RASTER ROTATION

a. Turn Raster Rotation 90^{o} left and 90^{o} right from dead centr (0^{o}) and return.

VI. TRACK WINDOW POSITION

a. Move window in VERT and return to center.
b. Move window in HORIZ and return to center.

VII. TRACKER SENSITIVITY

a. With target on coarse and fine, place target contrast to both and sensitivity from min. to max. to cause track lights to energize.

VIII. TURRET DRIVE

a. Place MTS at 0° -0° and press torquer power. Turret should slave to MTS. Have MTS drive turret in azimuth and elevation. Return to 0° -0°.

TABLE II

AIRPLANE EQUIPMENT NORMALLY ON
IN A CRUISE CONFIGURATION

1. Aux Hydraulic Pumps
2. Pilot's and Copilot's Instrument Gyro Switches
3. Autopilot (Engage Servo Motors)
4. Eight (8) Fuel Boost Pumps
5. Two ADF Radios
6. Two TACAN Receivers
7. Two VOR Receivers
8. Two VHF Radios
9. Two UHF Radios
10. Two HF Radios
11. Navigation Lights to Flash
12. APN-147 On
13. Loran (APN-70)
14. APN-59 On
15. Window Heat Normal
16. Pitot Heater
17. Q Inlet Heater
18. Rotating Beacon (5 minutes restriction)

b. Flight Tests

(1) PMEE system operational checks and EMC with ALOTS. All the functions shown in Table III were accomplished to verify normal PMEE system operation.

HF interference was evaluated at different transmitter modulations and frequencies utilizing the antennas on the wing tips, fin tip and the trailing wire antenna. The results are shown in Table V. The ALOTS video monitors and servo system as installed on the NKC-135 are known to be responsive to HF transmission at frequencies below 14 MHz; the interference causes heavy modulation of the video and causes the servo system to jitter and lose track. The same problem was encountered with ALOTS on the A/RIA.

The PMEE system operational checks and electromagnetic compatibility checks were run concurrently.

After airplane engines were started the ALOTS equipment was turned on. Shortly after take-off the PMEE equipment was turned on, one OA cabinet at a time, OA-1 through OA-27. A switching transient was noted on the ALOTS video monitors when the PMEE auxiliary cooling blower was turned on. A switching transient was also noted as OA-16 was turned on. No other RFI was noted.

After turn-on was completed, PMEE Verification was accomplished, the only interference noted at ALOTS was due to HF transmission.

Upon completion of PMEE Verification, the ALOTS equipment was run through its entire operational environment as per Parts II through VIII of Table I. No interference was noted on either the PMEE or ALOTS equipment.

Three data runs were made against the ground station.

The ground station was configured as shown in the block diagram in Figure IX-3. The "standard" Category II Test "race track" pattern was flown as described in Figure 2. While the PMEE equipment was tracking the ground station, the ALOTS equipment was operated.

Data Run #1

During the run, the HF was operating teletype in the blind on 17.553 MHz. All modes of L-Band tracking were selected with good tracking and no interference was noted. All data were recorded on Wideband Recorder #2 and VHF voice transmissions were carried on with the ground. Rate memory was checked after Point 5 with good results. No interference was noted on either the PMEE or ALOTS throughout the run.

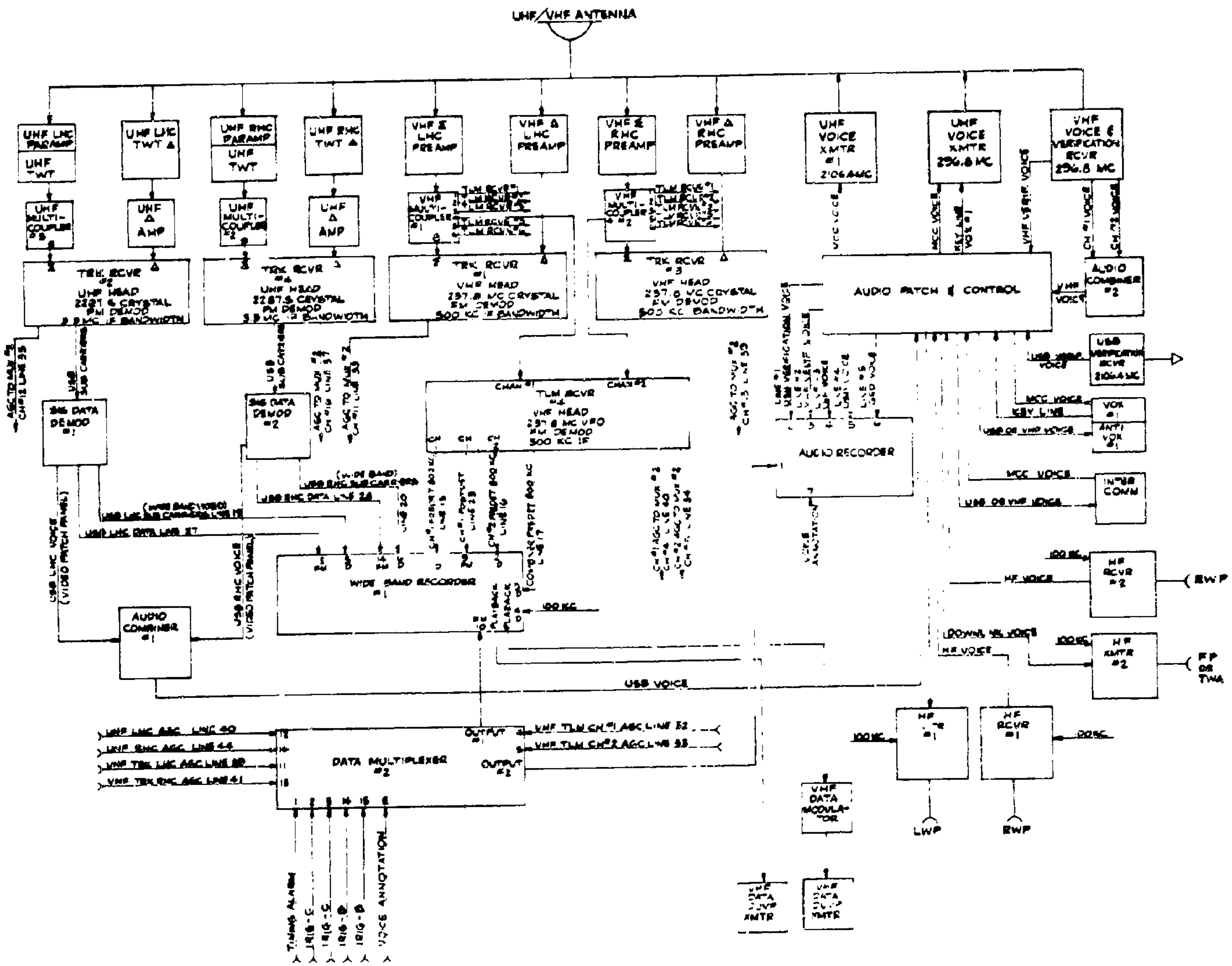

FIGURE IX-3. PMEE SYSTEM CONFIGURATION FOR ALOTS COMPATIBILITY TESTING

TABLE III

PMEE FUNCTIONAL CHECKOUT WITH TULSA GROUND STATION

	ACQUISITION						DURING AUTO TRACK							
	SCAN		ACQ		MODE		FREQ	PMEE COMM		TLM RECORD				Rate
Test	SS	MS	AA	MA	Freq	Polar		VHF	HF	VHF	UHF	USB	TTY	MEM
A	X		X		UHF	LHC	S-Band	X						
B		X		X	VHF	OPT	P-Band	X	X	X		X		
C		X		X	VHF	RHC	P-Band	X	X	X		X		
D		X		X	VHF	LHC	P-Band	X	X	X		X		X
E	X		X		UHF	OPT	S-Band	X	X	X		X	X	
F	X		X		UHF	RHC	S-Band	X	X	X		X		
G	X		X		UHF	LHC	S-Band	X	X	X		X	X	X
H	X		X		UHF	OPT	L-Band	X	X	X	X		X	X
I	X		X		UHF	RHC	L-Band	X	X	X	X			
J	X		X		UHF	LHC	L-B	X	X	X	X			

Legend:

SS - Sector Scan

MS - Manual Scan

AA - Automatic Acquisition

MA - Manual Acquisition

RHC - Right Hand Circular Polarization

LHC - Left Hand Circular Polarization

OPT - Optimum (Best of LHC or RHC)

TLM - Telemetry Data

TTY - Teletype

USB - Unified S-Band

Data Run #2

During the back leg of the "race track" pattern, between Runs 1 and 2, the L-Band tracking receivers were reconfigured for Unified S-Band tracking. Run #2 was utilizing VHF tracking with S-Band being phased in the air. All modes of VHF tracking were tried and no interference between PMEE and ALOTS was noted. During this run a special test was performed utilizing HF at 13.218 MHz. This was to determine if the PMEE antenna would be driven off by the HF while tracking on 237.8 MHz. During the test the PMEE antenna did not drive off, but audio was heard in the background. During the transmissions by HF, the ALOTS tracking was completely blocked. At Point 5, on the "race track" pattern, a rate memory check was performed with good results.

Data Run #3

Tracking and acquisition were accomplished on UHF. Again during this run both ALOTS and PMEE were monitored for interference; none was noted. During the run teletype was transmitted in the blind at 17.553 MHz and VHF voice transmissions were carried on utilizing 296.8 MHz. At "race track" pattern point 5 Rate Memory was checked.

(2) Operational Evaluation - Simultaneous Acquisition and Tracking Simultaneous tracking by PMEE and ALOTS of an airborne target was conducted with the NASA (422) C-121 Apollo simulator at 16,000 feet and the A/RIA at 12,000 feet. The relative position of the C-121 was changed such that it passed from the PMEE zone of surveillance to the ALOTS and vice versa. No intersystem interference was detected during the acquisition and tracking phases of either system. The PMEE was functionally checked with the target C-121, as shown in Table IV.

Once a rendezvous was accomplished, the A/RIA dropped behind the C-121. PMEE acquisition was on VHF/OPT. Data were recorded in both VHF and UHF. The PMEE acquisition was accomplished with the following antenna settings: 50^{o} Left Az and $+8^{o}$ E. Teletype transmissions were sent in the blind on 6712.0 MHz. This frequency caused considerable interference to the ALOTS equipment. The frequency was shifted to 1755.3 MHz. At 20:55 GMT, ALOTS started tracking the C-121. PMEE antenna position at that time was 117^{o} Left Az, $+9^{o}$ E. Both PMEE and ALOTS tracking continued with no interference noted in either system. At 21:01 ALOTS lost track with the PMEE antenna at 70^{o} LEFT Az and $+8^{o}$ E. PMEE continued tracking until 21:06 GMT. At this time PMEE track was broken off and the C-135 was "dirtied up" to reduce the speed and allow the C-121 to pass. The PMEE antenna acquired on UHF/OPT, utilizing sector scan, auto acquisition. PMEE acquired at 21:11:55 with the antenna at

TABLE IV

PMEE FUNCTIONAL CHECKOUT WITH TARGET C-121 APOLLO SIMULATOR AIRCRAFT

ACQUISITION							DURING AUTO TRACK					
	SCAN		ACQ		MODE		FREQ	PMEE COMM		TLM RECORD		
Test	SS	MS	AA	MA	Freq	Polar		VHF	HF	VHF	UHF	TTY
A	X	X		X	VHF	OPT	P-Band	X	X	X	X	X
B	X		X	X	UHF	OPT	S-Band	X	X	X	X	X

Legend:

SS - Sector Scan

MS - Manual Scan

AA - Automatic Acquisition

MA - Manual Acquisition

OPT - Optimum (Best of LHC or RHC)

TLM - Telemetry Data

TTY - Teletype

124° Left Az, +8° E. ALOTS acquired at 21:13:46 with antenna Az 72° Left E +7°. Tracking continued on both systems until 21:18 GMT, with no interference. At that time ALOTS reached its limit with the PMEE antenna at 113° Left Az, +06° E. PMEE continued tracking to limits. The above runs were repeated twice more to insure that no intersystem interference was present and comparable results were obtained.

(3) Environmental System Tests

(a) Airconditioning

A head-level and foot-level temperature survey was conducted at the ALOTS operator's stations as follows: (Results are shown in Table VI.)

In a cruise configuration at altitudes of 12,000 feet, 30,000 feet, and 37,500 feet, the head-level and foot-level temperatures at both ALOTS operators' positions and console cooling air inlet and exhaust temperatures were taken every 5 minutes for a minimum of 40 minutes with an Aneomtherm Model 60 portable temperature reading device ($\pm$ 1/2° F accuracy).

Cabin altitude was set to follow a normal schedule; all PMEE was operating; one PMEE cooling system fan was operated continuously; PMEE temperature control switch was in "auto" position; adjustable air outlets were open but were not permitted to blow directly onto the test temperature probe.

(b) Defogging

A qualitative evaluation of the MTS dome defogging was made by turning on the system fan and heater during airplane descent from 37,500 feet altitude to 12,000 feet. The dome remained clear and free of fog throughout the test flight.

(c) Oxygen

The oxygen equipment was evaluated as to accessibility and usability during the flight. The equipment is conventional — standard Air Force issue — and was deemed to be conveniently located and accessible. There may be a problem of insufficient equipment; however, the AFETR personnel aboard indicated that it is the practice to use four or five ALOTS operators even though there are provisions for only two (see the Personnel Subsystem Test and Evaluation Section for more discussions on this latter point).

(4) Acoustics

Sound pressure levels (SPL's) were obtained at the ALOTS manual tracking station and ALOTS console operator's position. Test instrumentation, equipment calibration, and data acquisition and analysis techniques were similar to those reported in Vol. III of DEV 3769, Section 3. 4.

Measurements were taken while both ALOTS and A/RIA Primary Mission Electronic Equipment were functioning in flight. Acoustical noise recordings were obtained at ear positions of both ALOTS crew stations during the following cruise flight conditions:

Altitude - 30, 000 feet

Mach No. = 0. 75 (V_{cruise} for max. range)

Indicated Airspeed = 285 knots

Cabin Altitude = 5, 000 feet

Gross Weight - 192, 000 pounds

4. 3 PERSONNEL SUBSYSTEM TEST AND EVALUATION (PSTE)

The PS evaluation of the A/RIA system is derived from the original proposal document, Report No. 52931, and the PSTE Annex, TU 28325. The scope of the Category II ALOTS compatibility with the A/RIA system is outlined in Supplement 1 to the Category II Test Procedures, Report No. DAC 56171, dated 8 May 1967. With these documents used as guidance, a detailed checklist was derived to cover the areas of investigation and inquiry during this evaluation. A copy of the checklist is presented in Annex A. The principal areas of interest were: equipment characteristics, environment, workspace, safety, procedures, communications, personnel manning, training, and technical publications. This evaluation included the use of the noted checklist, Personnel Subsystems Interview Reports, study of available documentation on the ALOTS, and personal observations and inquiries during the test flight on 25 May on A/RIA No. 4 (AFSN 61-327).

5.0 RESULTS AND CONCLUSIONS

5.1 GROUND TESTS

During the ground tests it was determined that the ALOTS operates normally on either ground power or with engines running.

It is understood by the contractor that tests made by Nortronics on the ALOTS system originally installed in the NKC-135 showed that both conducted and radiated broad band interference generated by the Photo Camera Drive motor exceeded MIL-I-6181D limits. To suppress this interference a separate ALOTS power supply was installed on the NKC-135 airplane. Part of the rework accomplished by Nortronics on the console prior to re-installation in the A/RIA airplane was installation of filters to remedy this condition, so that the ALOTS can use normal ship's power. Operation of the 70-mm photographic camera drive motors on the ground either with ground power to the airplane or with engines running revealed that interference still occurs in the ALOTS video and servo systems. In the opinion of the AFETR ALOTS specialists (Mr. John Shauman of PAA) interference in AUTO-track is as bad as, or worse than, the original NKC-135 installation.

Although earlier Category I electromagnetic compatibility tests revealed that the ALOTS video monitors and servo systems are susceptible to HF transmissions when keyed at frequencies below 14 MHz, no noticeable degradation of ALOTS was found during this series of ground tests when the HF transmitter was keyed and voice modulated at 6.625 and 10.750 MHz.

5.2 FLIGHT TESTS

a. Electromagnetic Incompatibility (EMI). EMI was found between HF transmission and the ALOTS. Heavy interference, severe enough to prevent ALOTS tracking, was found at 12.5 MHz and below with the wing probe antennas, at 13.5 MHz and below with the trailing wire antenna and at 13.0 MHz and below with the vertical fin tip antenna. The complete survey is tabulated in Table V.

b. Operational Evaluation Simultaneous Acquisition and Tracking. The flight against the C-121 Apollo simulator aircraft proved that it is feasible to acquire and track the same target with the A/RIA's PMEE and with ALOTS. At a PMEE antenna elevation angle of 8° to 9°, there was a 47° overlap in azimuth and at 6° to 7° elevation the overlap was 41° (in azimuth). Since this was with the limited field of view provided by the slotted aluminum plate, it is apparent that the UHF/VHF antenna will completely overlap the ALOTS with the proper window installed. (See Figure IX-4.)

c. Environmental Systems

The airconditioning load imposed by the ALOTS control console, astrodome, manual tracking station and the operators is calculated to be 12,770 BTU/HR (Ref. A/RIA RFP ES5-50229). This is about 16 percent of the 79,840 BTU/HR heat load of the PMEE (when all PMEE is operating). Detailed quantitative flight testing on A/RIA

TABLE V

HF-ALOTS COMPATIBILITY IN FLIGHT
EC-135N AIRCRAFT NO. 61-327

Flight No. 29
25 May 1967

Test	XMTR	Freq	Ant	Notes	Results
1	PMEE	6.712	LWP	1	Heavy Interference - no track
2	PMEE	14-11	LWP	1, 3	13.5 and 13.0 MHz light interference - possible track 12.5, 12.0 11.0 MHz heavy interference - no possible track
3	PMEE	6.712	RWP	1	Heavy Interference - no track
4	PMEE	14-11	RWP	1, 3	13.5, 13.0, 11.0 MHz light interference - possible track 12.5, 12.0, heavy interference - no track
5	PMEE	6.712	TW	1	Heavy interference - no track
6	PMEE	14-11	TW	1, 3	14, 11.5, 11 MHz, light interference - possible track 13.5, 13, 12 MHz, heavy interference - no track
7	PMEE	6.712	FP	1	Heavy interference - no track
8	PMEE	14-11	FP	1, 3	14, 11.5, 11 MHz, light interference - possible track
9	Liaison	6.712	FP	2	Heavy interference - no track
10	Liaison	14-11	FP	2, 3	14, 12, 11 MHz, light interference - possible track 13.0, 12.5 MHz, heavy interference - no track

NOTES:

1. Modulated A1 sideband with voice, and B1 sideband with TTY.
2. Modulated upper sideband with voice.
3. Reduced transmitter frequency in .5 MHz increments starting at 14 MHz.

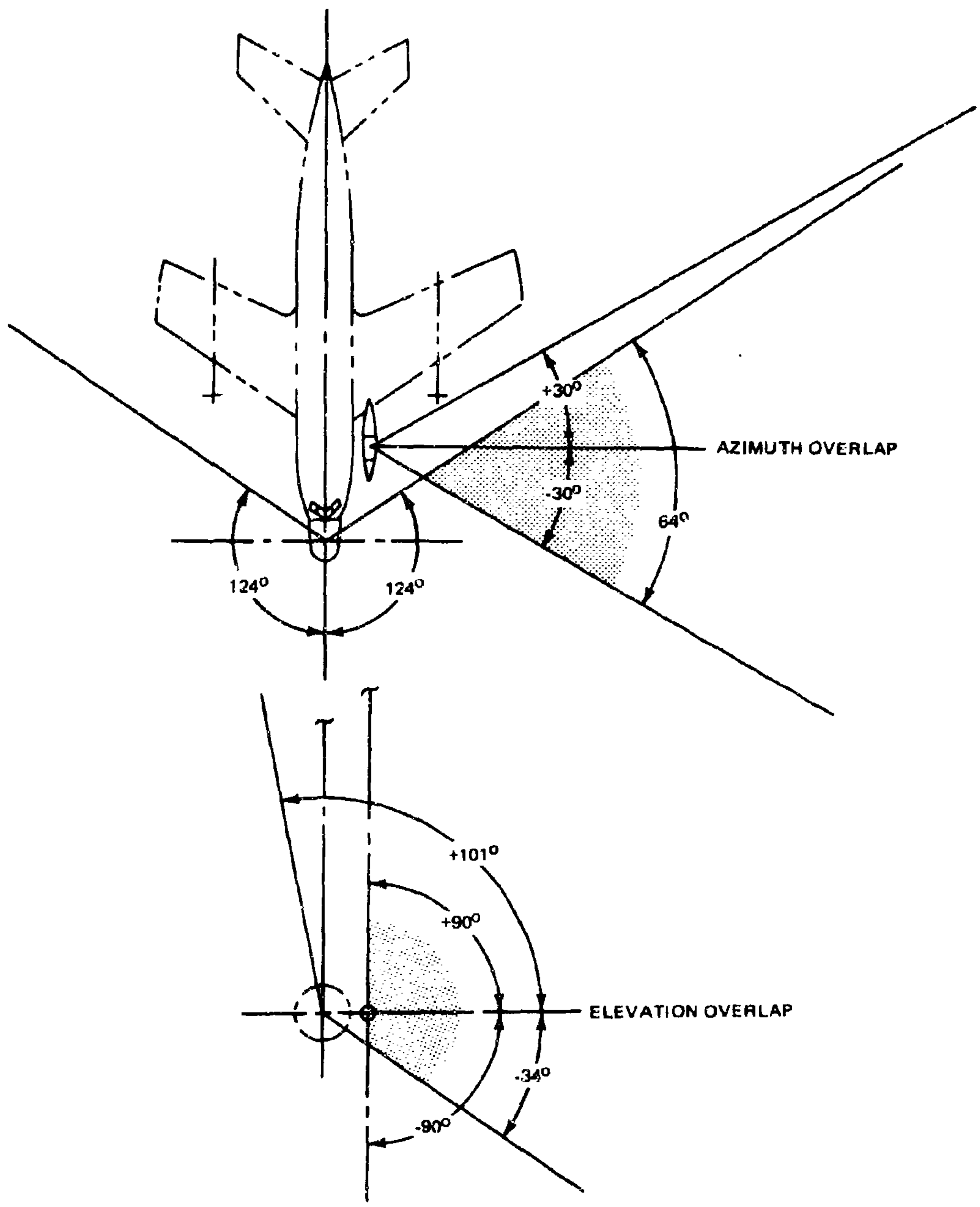

FIGURE IX-4. OVERLAP AREA COMMON TO A/RIA AND ALOTS EQUIPMENT

is more than adequate for absorbing the subsystem's heat loads. It was found that in the PMEE configuration there was no difficulty in maintaining an average compartment temperature at 70°F within the airplane operating limits of +20°C RAM air temperature (RAT-indicated) and -40°C RAT (Ref. Vol. III of Report DEV 3769).

The cabin temperature survey in the ALOTS area showed that temperatures at the console operator's and MTS operator's stations were comfortable and comparable with the rest of the A/RIA operators' stations. The temperatures at the two stations differed by a few degrees, sometimes one way and sometimes the other; in other words one station is not characteristically hotter or colder than the other. The mean differential head to foot level temperatures were 3°F at the console and 2°F at the MTS. Console cooling inlet temperatures appear to be adequate to maintain sufficient cooling. Temperature survey information is presented for 3 altitudes in tabular form in Table VI.

The MTS dome defogging kept the dome clear and free of fog during a descent from 37,500 feet to 12,000 feet. There was a noticeable increase in the cabin ambient temperature at the MTS with the defogging heater on.

d. Acoustics

Sound pressure levels at the ALOTS positions were generally the highest measured within the A/RIA equipment compartment. This was anticipated due to the local effects of separated flow and thickening of the boundary layer caused by the ALOTS pod, its struts, and the ALOTS manual tracking dome protuberance.

Data in the Table below (in decibels) indicate SPL's at the ALOTS console operator's position exceed the equipment compartment (instrumentation area) octave band specification levels by as little as 5.7 dB and as much as 30.1 dB. Similarly the speech interference level (SIL) and loudness level (L. L.) specifications were exceeded at both ALOTS crew positions.

Acoustical noise levels (in decibels re 0.0002 microbar) are shown in graphical form in Figure IX-5.

Note: Eng. EPR = 2.34 N_2 = 89%	OVER ALL	OCTAVE BANDS								SIL	L.L.
		1	2	3	4	5	6	7	8		
		FREQUENCIES – CPS									
	45/11200	45/90	90/180	180/355	355/710	710/1400	1400/2800	2800/5600	5600/11200		Phon
ALOTS Manual Tracking Station	106.9	98.0	103.1	95.6	94.4	98.7	89.1	87.0	82.1	91.7	110.5
ALOTS Console Operators Posn	98.4	90.8	93.4	85.5	93.1	89.4	81.6	77.3	77.3	84.5	103.1
Equip. Compt. Spec. Levels		77.0	77.3	78.4	77.8	72.3	68.0	62.3	52.0	70.3	92.3

TABLE VI

ALOTS TEMPERATURE SURVEY

Test No. 1: Airplane Alt – 30,000 ft; Cabin Alt – 6,000 ft

Time Min.	Head Console	Head Dome	Foot Console	Foot Dome	Rat °C	Inlet Console
0	73	65	67	63	-14	73
5	63	71	63	68	-13	64
10	64	75	62	69	-13	63
15	65	69	63	67	-13.5	63
20	64	74	61	67	-14.5	62
25	63	67	60	65	-14	62
30	63	67	60	65	-14	62
35	65	70	60	68	-14	63
40	63	67	60	65	-14	62

Test No. 2: Airplane Alt – 37,500 ft; Cabin Alt – 10,000 ft

Time Min.	Head Console	Head Dome	Foot Console	Foot Dome	Rat °C	Inlet Console
0	65	63	73	67	-32	73
5	71	68	63	63	-32	64
10	75	69	64	62	-32	63
15	69	67	65	63	-32	63
20	74	67	64	61	-32	62
25	67	65	63	60	-32	62
30	67	65	63	60	-32	62
35	70	68	65	60	-32	63
40	67	65	63	60	-32	62

Test No. 3: Airplane Alt – 12,000 ft; Cabin Alt – 2,000 ft

Time Min.	Head Console	Head Dome	Foot Console	Foot Dome	Rat °C	Inlet Console
0	89	90	87	89	+15	82
5	88	89	85	88	+15	85
10	86	89	85	85	+18	85
15	84	85	83	87	+18	83
20	85	85	84	87	+18	84
25	84	86	84	87	+18	84
30	84	86	84	86	+18	83
35	85	86	84	86	+18	84
40	85	85	84	86	+18	84

NOTE: 1. All tests run with PMEE auxiliary fan only (main fan was inoperative).

2. All temperatures in °F except for RAT.

A/RIA No. 4 (61-327) Flight 29, 5-25-67
Altitude = 30,000 Ft. Cabin Alt. = 5,000 Ft.
Airspeed = 285 KIAS Mach No. = 0.75
Gross Weight = 192,000 Pounds

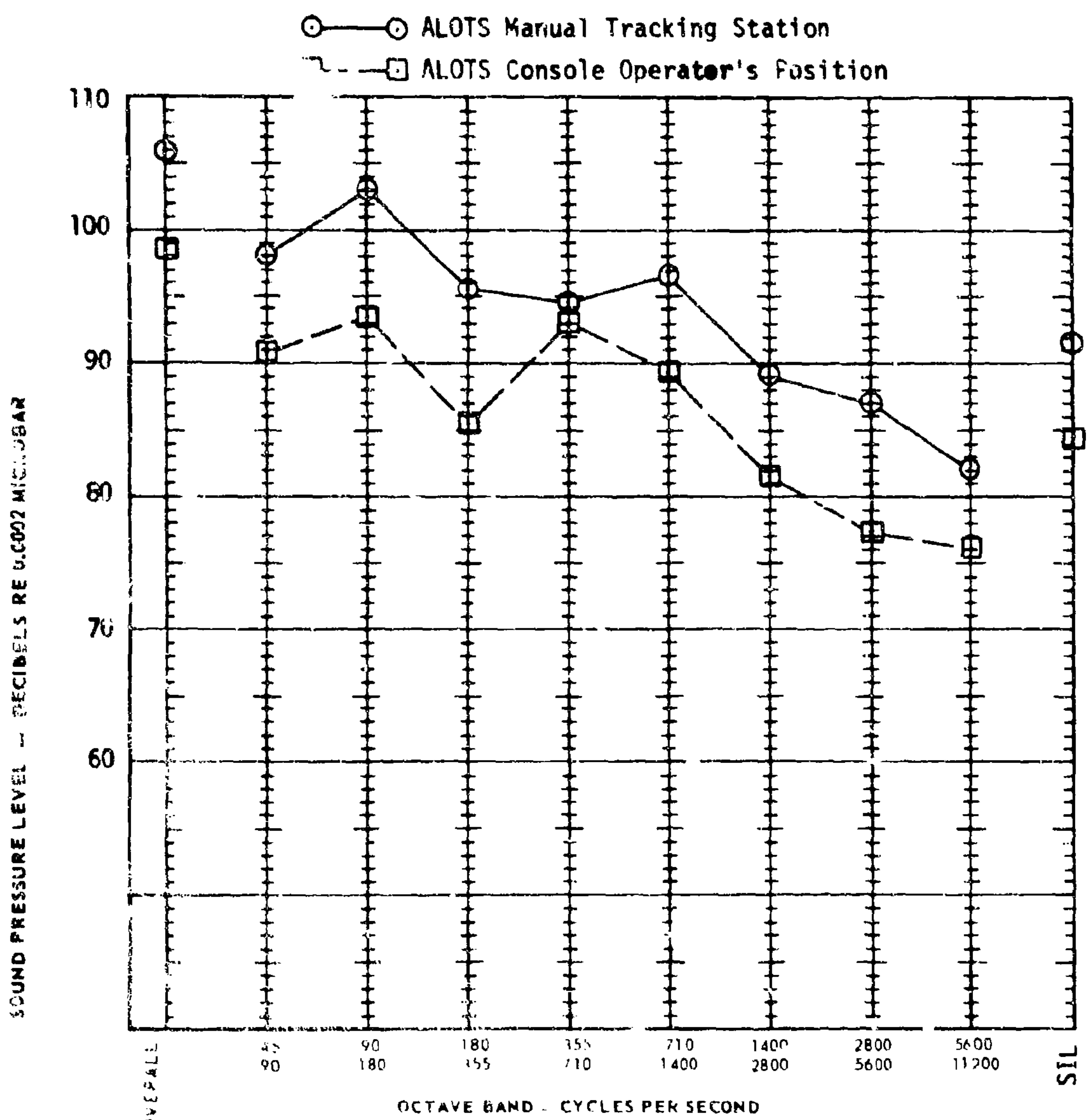

FIGURE IX-5. A/RIA-ALOTS CRUISE FLIGHT SOUND PRESSURE LEVELS

5.3 PERSONNEL SUBSYSTEM TEST AND EVALUATION (PSTE)

From a PSTE standpoint the operation of ALOTS has many inadequacies, most of which are not a result of the installation on the A/RIA. The bulk of the inadequacies can be traced to the need for more men to operate the system than there are stations provided for on the aircraft.

A completed ALOTS PSTE checklist is presented in Annex A and interview reports with the ALOTS personnel are presented in Annex B.

a. Equipment Characteristics

The ALOTS control console appears to be laid out for functional operation; however, it was originally designed for a single operator and the Air Force is presently using three men at the console to perform the mission. In addition to the regular operator a photographer is at the console whose task is to control the settings and operation of the camera; an additional instrumentation Technician, AFSC 31770, is carried, to maintain proper adjustment of the sensitivity of the TV monitors. This increase in the size of the ALOTS crew imposes problems on use of the controls, coordination between the operators, and the provision for life support. The requirement for two additional operators was discussed in detail with all Air Force personnel, and they were of the unanimous opinion that the mission could not be satisfactorily accomplished without the assistance of the photographer and the additional man for sensitivity control, because the console operator (prime) is completely occupied in the actual control of the tracking.

b. Environment

Due to the position of the control console, the console operator has a TV image which is actually reversed from the picture taken by the TV cameras. This causes a reversal in the apparent direction of motion on the monitor screen. However, once the image is in his monitor screen, his tracking requirements are identical to those which were experienced with the console on the opposite side of the cabin (on the NKC-135), and oriented the same as the camera. Apparently the only problem which might be encountered -- if in fact the reversed orientation might be a problem -- is in the area of initial target acquisition, when the operator might have an inherent tendency to misdirect the cameras, based on past experience, and the TV image as he sees it. The test mission did not reveal evidence of any definite problem associated with the console orientation.

The lighting and temperature control were considered satisfactory in the ALOTS area. The noise level in the console area is comparable to that observed in the rest of the cabin area, and not considered bothersome to the ALOTS crew members. The measured noise level in the MTS dome is significantly higher than at the normal work level in the cabin. The dome

de-fogging worked satisfactorily, both with and without heat. The oxygen equipment is adequate for the two crew positions provided; however, there are no provisions for life support or emergency equipment for the two additional crew members currently being utilized by the Air Force for the ALOTS mission.

c. Workspace

The workspace is cramped for three men at the control console. There appears to be adequate space for trouble-shooting, and in-flight maintenance of the ALOTS equipment. AFETR has a fly-away kit in readiness for deployment with ALOTS-equipped aircraft. No definite plans have apparently been finalized for adjusting the fly-away kit to the A/RIA mission and aircraft.

The EC-135N boarding ladder, as presently stowed on the inside of the cargo door, is definitely in the way, and a hazard to the movement of crew members about the ALOTS area. In addition, the ladder comes in contact with bundles of control wires going through the door to the ALOTS pod, subjecting them to possible damage whenever the ladder is stowed or removed from its assigned stowage area. The ladder could be relocated to alleviate this condition.

There is a definite problem with exterior light shining on the control console, and interfering with the TV monitor screens. The console is located quite close to the MTS dome through which the light enters. This condition could be corrected by the installation of a curtain between the MTS operator position and the control console.

d. Safety

All emergency equipment is immediately available, although no provisions are made for the two additional ALOTS operators. A major problem is apparent in the MTS seat, and retaining seat belt. The seat, which was provided by the USAF, is much too low for the operator, necessitating the addition of a cushion which is approximately 10 inches in thickness. This makes it impossible for the operator to fasten the seat belt which is provided. This is considered a definite hazard in case of loss of the dome, and resultant cabin decompression. In addition, it is considered most desirable that some sort of a screen or grating be provided for the dome area, to be used when the ALOTS equipment is removed from the A/ARIA aircraft to prevent personnel hazards in case of decompression.

Alarm bells and signals were observed during pre-takeoff checks and are considered to be properly placed for the ALOTS crew members.

e. Procedures

The interphone procedures, and coordination activities of the ALOTS mission through the MCC, appear to be quite adequate. Captain Redmon, who was observer MCC on this flight and is also a qualified ALOTS officer, stated that in his opinion the procedures established are good.

f. Communications

The interphone control box is quite adequate on the ALOTS control console. The control box is not standard, either to the A/RIA aircraft or the PMEE equipment. It had to be specially wired for the installation, and the resultant performance was very noisy, and unsatisfactory. It is recommended that a control box, similar to those installed in the PMEE section, be installed on the partition wall immediately to the right of the control console, with provisions for a second interphone jack, for the additional photographer/operator. Isolation of the interphone from the console, such as the suggested location on the wall, would possibly lessen the interference observed in the system.

g. Personnel Manning

It is quite apparent that the Air Force requirements for personnel are not being reflected in the procurement of hardware. The proposal for the A/RIA system procurement reflected a requirement for only two ALOTS operators, as does the Nortronics ALOTS Handbook and marketing brochure. However, for some time AFETR has been using four or five operators for the ALOTS equipment on every mission requiring its use, and apparently they will continue to do so. Definite action will be required, either to authorize the appropriate personnel, or to modify the existing equipment so that the authorized personnel can operate it and perform the mission.

h. Training

No specialized training is available within the Air Force for ALOTS technicians/operators. The AFSC A31770 is used to identify the ALOTS operators, which is in the field of Instrumentation Technicians. A very small amount of photographic training might be included in such basic training. The additional photographic technician, normally carried for operation and control of the camera, is normally trained within the photographic field.

i. Technical Publications

No formal Technical Order has apparently ever been published for the ALOTS equipment. The Handbook currently in use (provided by Nortronics) is simply a commercial-type publication, and not in conformance with established T. O. requirements. Neither is there any provision within the A/RIA technical publications schedule for any procedures or checklists for the ALOTS equipment, or its operation when integrated with the A/RIA system. This is considered a serious discrepancy, one which should be corrected, at least to include abbreviated checklists and emergency procedures. It is most interesting to note that the AFETR personnel have developed their own checklists for operation of the ALOTS equipment, including both ground check-out and in-flight operations. They are markedly different from those presented in the Nortronics Handbook.

ANNEX A

PSTE CHECKLIST FOR A/RIA-ALOTS COMPATIBILITY FLIGHT

PSTE Observer J. R. Lyall
DACo

Equipment Characteristics

a. Q. Are any of the controls difficult to reach, operate, or read? If so, what are they, and any recommendations?

A. Yes. TV sensitivity - Left cabinet

b. Q. Are the controls and displays in the optimum location for readability and use? (Requirement for an utilization of multiple operators)

A. Yes

c. Q. Do any controls or displays appear to be unnecessary for performance of the normal tasks?

A. No

Environment

a. Q. Does the orientation of the control console with respect to camera view affect the control of the equipment?

A. Apparently not.

b. Q. Is the lighting adequate in the ALOTS area?

A. Yes

c. Q. Is the temperature control in the area adequate?

A. Yes

d. Q. Is the noise level in the area bothersome in the performance of the mission?

A. No

e. Q. Is the dome de-fogging provision adequate?

A. Yes

f. Q. Is the oxygen equipment conveniently located, accessible?

A. Yes - both O. K.

Workspace

a. Q. Is there adequate space in the area for the operators to perform tasks? (Space for multiple operators)

A. No - cramped for 3 operators.

b. Q. Is there adequate workspace for trouble-shooting equipment, and repair, in-flight and on the ground.

A. Yes

c. Q. Is there space for test equipment, and any spares possibly required in flight?

A. Yes

Safety

a. Q. Is all emergency equipment readily accessible to operators?

A. Yes

b. Q. Are any problems evident in possible in flight emergencies, such as getting out of positions, and taking emergency action?

A. Yes - difficult to get in and out of MTS.

c. Q. Is any potential hazard present in case of loss of dome, and ensuing decompression of cabin? Are seat belts utilized, and what is course of action in case of decompression?

A. Yes, no

d. Q. Are emergency procedures known by operators?

A. Yes

e. Q. Is alarm bell and signal in proper location for signals to ALOTS position?

A. Yes

Procedures

a. Q. Is the interphone procedure, as established with MCC control of ALOTS mission adequate in the performance of ALOTS tasks?

A. Yes

b. Q. Is the procedure for communications with the pilots adequate?

A. Yes

c. Q. Are the established procedures for operation of the control console correct and/or adequate?

A. Yes

d. Q. Is there an adequate pre-take-off checklist for the ALOTS positions?

A. No

e. Q. Are there any recommendations for improvements in established procedures for operation of the ALOTS equipment, or integration of it with the rest of the A/RIA system?

A. Use A/RIA interphone control. Odd ball box used - noisy.

Communications

a. Q. Is the interphone system as installed in the A/RIA aircraft adequate and satisfactory for the ALOTS equipment and mission?

A. No - only 1 outlet for console - should have a box like A/RIA - dual jack on wall.

b. Q. Can the ALOTS operator(s) communicate with all crew members required in the performance of ALOTS mission, and in emergencies?

A. MCC and pilot - yes

Personnel Manning

a. Q. Is the A/RIA aircraft properly manned for the ALOTS mission, either with the PMEE or as an ALOTS-only aircraft?

A. Undetermined

b. Q. What is the minimum number of ALOTS qualified operators required for the ALOTS mission?

A. Unknown

Training

a. Q. Are the ALOTS operators adequately trained to perform the mission, and maintain the equipment?

A. Yes

b. Q. Does the ALOTS equipment--and the A/RIA mission--require special training to qualify assigned personnel?

A. Yes

Technical Publications

a. Q. Is the ALOTS handbook, as provided and in current use, adequate for the operator and maintenance of the ALOTS equipment?

A. No

b. Q. Are the A/RIA Technical Orders adequate in the coverage of the ALOTS, as integrated into the system?

A. No - none. Should be integrated.

c. Q. Are checklists available, and in use?

A. No

ANNEX B

DOUGLAS
AIRCRAFT MODIFICATION DIVISION

PERSONNEL SUBSYSTEMS INTERVIEW REPORT

CATEGORY II   TEST ALO-13 COMM.

OPERATOR SSgt. Lindley, K.R. POSITION (NAME) Photographer (ALO13) (NO.) 1

Note: This form to be completed as soon as possible after the interview.

Can you recall any difficulty or problem experienced during task No.

If so, what was it

What do you think caused the difficulty

Was there a lack of equipment, procedures, tech. manuals that might make difficult for A.F. personnel (or someone less skilled than yourself) to perform the task

Did you deliberately add or delete any steps in the procedure Yes, Procedures (operating) developed

If so, why by ETR

Did the job or task take significantly longer than you had expected it to take NO

If so, why

How would you improve the equipment, procedure, technical manuals or anything else about the job Test mgt.

DOUGLAS
AIRCRAFT MODIFICATION DIVISION

PERSONNEL SUBSYSTEMS INTERVIEW REPORT

CATEGORY II TEST ALO-?, C5 V.R.

OPERATOR Schaumann, J.L. POSITION (NAME) ALO-? Eng. (Pos 4th) (NO.) 2

Note: This form to be completed as soon as possible after the interview.

Can you recall any difficulty or problem experienced during task No, except for hot air - late in mission

If so, what was it Hot air on console when descended to 12,000'

What do you think caused the difficulty no air cond. Was taking air out. [illegible]

Was there a lack of equipment, procedures, tech. manuals that might make difficult for A.F. personnel (or someone less skilled than yourself) to perform the task NO [illegible] or checklists.

Did you deliberately add or delete any steps in the procedure Whole new [illegible]. (operating)

If so, why

Did the job or task take significantly longer than you had expected it to take No

If so, why

How would you improve the equipment, procedure, technical manuals or anything else about the job Modify seat : [illegible] [illegible] swivel seat parts. Curtain between [illegible] & console.

FORM 11C (REV. 4-58)

DOUGLAS

AIRCRAFT MODIFICATION DIVISION

PERSONNEL SUBSYSTEMS INTERVIEW REPORT

CATEGORY II TEST [illegible]

OPERATOR [illegible] POSITION (NAME) [illegible] (NO.) 3

Note: This form to be completed as soon as possible after the interview.

Can you recall any difficulty or problem experienced during task Cannot fasten MTS seat belt Require

If so, what was it large cushion to raise operator high enough to sec.

What do you think caused the difficulty

Poor seat design No provision for belt in proper position.

Was there a lack of equipment, procedures, tech. manuals that might make difficult for A.F. personnel (or someone less skilled than yourself) to perform the task [illegible]

Did you deliberately add or delete any steps in the procedure No

If so, why

Did the job or task take significantly longer than you had expected it to take No

If so, why

How would you improve the equipment, procedure, technical manuals or anything else about the job Revise seat belts for MTS operator.

DOUGLAS

AIRCRAFT MODIFICATION DIVISION

PERSONNEL SUBSYSTEMS INTERVIEW REPORT

CATEGORY II TEST ALOTS COMPT.

OPERATOR Capt. Redmon, H. L. POSITION (NAME) (NO.) 4

Assigned Officer

Note: This form to be completed as soon as possible after the interview. I DID NOT OBSERVE THE ALOTS SYSTEM DURING THIS FLIGHT. I WAS FLYING AS PILOT OBSERVER AND THEREFORE SPENT VERY LITTLE TIME IN ALOTS COMPARTMENT.

Can you recall any difficulty or problem experienced during

task ______ by Capt. [illegible]

If so, what was it ______

What do you think caused the difficulty ______

______

Was there a lack of equipment, procedures, tech. manuals that might make difficult for A.F. personnel (or someone less skilled than yourself) to perform the task ______

______

Did you deliberately add or delete any steps in the procedure ______

If so, why ______

Did the job or task take significantly longer than you had expected it to take ______

If so, why ______

How would you improve the equipment, procedure, technical manuals or anything else about the job ______

______

Note: Capt Redmon spent approximately 30% of mission time in ALOTS area. [illegible]

6.0 RECOMMENDATIONS

The following recommendations are made for improvement in equipment, environment and procedures in operating the ALOTS, as integrated into the A/RIA system:

a. Provide additional personnel stations with necessary life support equipment and communications in the vicinity of the ALOTS console to recognize the requirement for the number of personnel needed to operate the system or

b. Provide means for automating the camera controls and TV sensitivity, so that a single operator may control the system through the control console. This would not only simplify operation of equipment, but also reduce the number of personnel required for manning the system, thus relieving the congestion in the ALOTS workspace and eliminating the requirement for addition life support equipment and communication equipment.

c. Relocate the aircraft boarding ladder so as to remove the hazards involved with its present mounting on the cargo door. In addition to the hazard to personnel movement through the area and possible damage to ALOTS cabling, it restricts the workspace of the ALOTS operators.

d. Modify the MTS seat so that the operator may use the sight, and still get the safety belt fastened. The seat is installed as provided by the Air Force, and constitutes a safety hazard without a usable seat belt.

e. Install an A/RIA-type intercommunications control box on the partition wall immediately to the right of the ALOTS control console -- with multiple jacks, if continued use of multiple operators is anticipated.

f. Provide and/or modify A/RIA Technical Orders and Abbreviated Checklists so as to include all the necessary procedures for operation of the ALOTS equipment, as integrated into the A/RIA system.

g. Install a curtain between the MTS and control console, to reduce the exterior illumination of the console and the TV monitor screens.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT The A/RIA system is designed to provide voice and telemetry data communication with Apollo and other spacecraft, with a capability to relay all communications to the Manned Spaceflight Network, and record all telemetered data on board. The system includes a basic C-135A aircraft, modified to accept and support the electronics equipment and automatic tracking antenna required to perform the mission. The purpose of the Category II flight test program was to verify that the system could acquire and track an orbiting space vehicle--and trajectory of ballistic missiles--using VHF, UHF, and Unified S-Band frequencies, with simultaneous recording and two-way voice link with ground stations via HF. Quantitative system testing was performed at Douglas Aircraft, Tulsa, Okla.; operational evaluations included coverage of Gemini XII, a Polaris ballistic missile, and simulated Apollo coverage through use of a NASA C-121 Apollo Simulator. Tests demonstrated system capability to acquire and track an Apollo vehicle at the radio horizon, a range of approximately 1200 nautical miles on VHF, with an expected data bit error rate of 1×10^{-4} in the data link. On the Unified S-Band, the expected range is 900 nautical miles, with an expected data bit error rate of 1×10^{-4}. HF communications have been demonstrated at ranges up to 5500 nautical miles, using simplex, duplex, single sideband, independent sideband, frequency diversity, and sideband diversity. Extrapolation of the test results to the expected operational performance of the Apollo spacecraft indicates that the A/RIA system will fulfill the design requirements, and perform its assigned mission.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
A/RIA--Apollo Range Instrumented Aircraft						
ALOTS--Airborne Lightweight Optics Tracking System						
EC-135N--Designation of A/RIA-modified C-135A						
PMEE--Prime mission electronics equipment--on A/RIA						
OSP--On-Station Position (of aircraft)						
Unified S-Band						
Rate memory						
UHF/VHF Tracking Antenna						
Data dump						